Aalto University
School of Engineering

Premise-based construction cost estimation in residential production in St. Petersburg, Russia

Aalto University
School of Engineering
Faculty of Engineering and Architecture
Department of Real Estate, Planning and Geoinformatics
Master's Thesis

Espoo, 26 February 2014

Bachelor of Arts in Business Administration Oleg Forbatok
Supervisor: Professor Seppo Junnila
Instructor: M. Sc. (Tech.) Pekka Eskola

Aalto University
School of Engineering

Aalto University, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

Abstract of master's thesis

Author Oleg Forbatok	
Title of thesis Premise-based construction cost estimation in residential production in St. Petersburg, Russia	
Degree programme Degree programme in Real Estate Economics	
Major/minor Real Estate Investment and Finance	**Code of professorship** Maa-20
Thesis supervisor Professor Seppo Junnila	
Thesis advisor(s) M.Sc. (Tech) Pekka Eskola	
Date 25.02.2014	**Number of pages** 72 **Language** English

Abstract

Estimation of construction costs is a common practice among players in the construction industry. Construction project is a complex process that requires financial and resource planning. Regardless of the cost estimation's importance, the research material on the subject is relatively limited.

The purpose of this study is to elaborate on current methodologies used in the project cost estimation in the construction industry, to analyze the current construction cost estimation model used by the case company, and to research for the ways to adapt the existing model for estimation of residential production in St. Petersburg, Russia. This leads to the following research questions:

- According to the existing studies, what are the main cost estimation methodologies applied by practitioners?
- Can the existing estimation model used by the case company be implemented in St. Petersburg, Russia?
- Is the estimated model reliable for St. Petersburg, Russia?

The findings of the literature review indicate the important of the cost estimation at the early phase of the construction project, e.g. before the design planning stage.

The study describes the role of the cost estimation and its optimal utilization in the design management process of the case company. Also, the study analyses how target costing methodology has been applied in company's solution for optimization of construction cost estimation process.

This research uses case study methodology to research for possibilities of adaptation the existing estimation model in company's residential production in St. Petersburg, Russia. The case study analyzes the adjustment process of technical parameters and units' price. The key finding of the case study is that existing cost estimation model used in the company is suitable for estimation in St. Petersburg, Russia, but requires essential setup in the price adjustment. This leads to the fact that market prices used in this case cannot be adjusted for a cross-border usage only via indexing of materials and labor units. For the model to be reliable, the material and labor prices database has to be based on the local price market information.

Evidence for the need of the optimized solution for construction cost estimation has been found in answers provided by interviewees. The interview answers also provide the importance of the model consistency used in cost estimation process.

Keywords construction cost estimation, residential production, estimation model, St. Petersburg

Aalto University
School of Engineering

Aalto University, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

Краткое содержание

Автор Олег Форбаток

Тема Исследование автоматизации бюджетирования ИСП в жилищном строительстве на этапе бизнес-планирования в Санкт-Петербурге

Специальность Экономика недвижимости

Специализация Инвестиции в недвижимость и финансы **Код** Maa-20

Куратор Профессор Сеппо Юннила

Руководитель Дипломированный инженер Пекка Эскола

Дата 26.02.2014 **Количество стр** 72 **Язык** Английский

Краткое содержание

Оценка стоимости инвестиционно-строительного проекта (ИСП) на этапе бизнес-планирования является распространённой практикой среди компаний в строительной отрасли. ИСП представляет собой систему сформулированных целей для реализации объектов недвижимости, в том числе организацию материальных, финансовых и трудовых ресурсов по их выполнению. Несмотря на важность бюджетирования на этапе бизнес-планирования, научный материал по этой теме доступен в ограниченном количестве. Целями настоящей работы являются определение текущих методов, используемых в оценке стоимости ИСП, анализ текущей модели оценки стоимости ИСП на этапе бизнес-планирования, и адаптация существующей модели для оценки затрат на этапе бизнес-планирования ИСП в жилищном строительстве в Санкт-Петербурге. Это приводит к следующим исследовательским задачам:

- Определить основные используемые методы оценки стоимости на этапе бизнес-планирования ИСП.
- Определить возможность реализации существующей модели по бюджетированию на рынке в Санкт-Петербурге.
- Определить соответствие результатов подсчета модели с допустимой погрешностью.

Теоретическая часть работы объясняет важность процедуры оценки стоимости на этапе бизнес планирования ИСП, следствием чего является обязательное проведение предварительного бюджетирования до этапа проектирования.

Исследование описывает роль процесса оценки затрат и его оптимального использования в системе управления проектированием на примере-компании. Кроме того, мы анализируем методологию целевого учета затрат на строительство и его реализацию в системе подсчета строительных расходов.

Практическая часть работы заключается в исследовании путей адаптации модели по оценке затрат на этапе бизнес-планирования ИСП в жилищном строительстве. Мы анализируем процесс настройки технических параметров и их стоимости. Результатом практического исследования является то, что существующая модель оценки стоимости ИСП на этапе бизнес-планирования может быть использована на рынке в Санкт-Петербурге только после существенной корректировки единичных расценок применимых для исследуемого рынка. Следствием этого является то, что рыночные цены, рассматриваемые в модели, не могут быть откорректированы только при помощи корректировки базы расценок. Чтобы модель оценки строительных затрат предоставляла достоверный результат, база расценок, взятая за основу подсчета, должна базироваться на данных по среднестатистическим ценам того региона, где производится расчет.

Ключевые слова оценка строительных затрат, жилищное строительство, экономическая модель, Санкт-Петербург

Acknowledgements

This master's thesis is conducted for NCC Real Estate in St. Petersburg, Russia. I would like to thank especially my thesis instructor Pekka Eskola who has given me a great deal of support and input during the project and Juuso Hietanen who has approved the project start in the first place.

Thanks go to Esko Kerkkänen, Yulia Soloshenko, Klim Petrov, Anton Pavlov, Matti Alakulju, Marko Santala, Anna Feshchenko, and Alexander Boytsov for their time and effort during the data collection and processing for the study. Also, special thanks to Jouni Keisala and Sergey Vesolov for helpful tips and recommendations towards my thesis.

Thanks go to the thesis supervisor, Professor Seppo Junnila, for his professional insight and timely feedback during the project.

Thanks to my parents for their genuine interest in my studies and their support. Finally, special thanks to Matilda for an enormous amount of encouragement, support and understanding during this important phase of my life.

St. Petersburg, 26 February, 2014

Oleg Forbatok

Table of Contents

Table of Tables

Table of Figures

1 Introduction

1.1 Background

Cost estimation has always been a necessary part of the construction project planning. Its importance is justified because it is conducted during the initial stage of the project planning phase, therefore it becomes a driving component for a building design. Cost estimation process can be considered as the budgeting in the initial stage of the construction project, thus it determines the investment potential and profitability level for the decision makers. Being a driver for the construction project from the financial and design perspective, the cost estimation procedure is vital part of the project planning process and is necessary to be estimated as precisely and as possible.

Cost estimation process interacts with many stakeholders because the process requires information and understanding about preliminary financial allowance and expectation from the management, resources for architectural planning and design, and as well as the targeted group of potential users of the building. Term estimating by its nature implies risk of uncertainty, therefore it can be never 100% accurate. Nevertheless, as the construction project is a complicated process involving multiple planning and execution steps, it is important to conduct cost estimation procedure diligently using the most up-to-date and accurate data available.

In theory the cost estimation provides the methodology and a path for the costs calculation and consolidation, and in practice it identifies the value of the project and provides decision makers with the information regarding the construction project. Cost estimation also plays an important role in further decision making regarding the purpose of the project. As each cost estimation process has the purpose to deliver certain outlook towards a given possible construction project, it is reliable to refer to the term also as a target costing. According to Pennanen (2011) the importance of the target costing lies in defining project scope, quality level, conditions, client needs that also derive project schedule and cost estimates.

The primary need for the target costing is in the early phase of the project planning, e.g. before design of the project has been commenced. The cost estimation, as a matter of fact, is aimed to provide a framework for the building design. As mentioned before, the construction project is a complicated process which requires a lump sum of upfront investments. Even though the whole sum of the project can be enormous compared to the other investment options, the resource's allowance per individual parameter can be quite limited. Therefore the maximum accuracy of the construction cost estimation is vital for avoiding risk of a cost overrun.

We have outlined that the need for the cost estimation is in the early stage of the construction project when the information about the actual costs is most limited. Therefore computer-aided design (CAD) models fail to furnish the decision makers with proper and relevant information regarding the estimated project costs because the design parameters have not been yet confirmed (Pennanen, et al., 2011, p. 53). The reason for inefficiency of the design plans for cost estimation in the early stage is that one cost profile can result in several different designs, and design does not identify the purpose of the project, but vice versa, the defined project leads to several design options. This leads to the problem of too much input parameters influencing the cost of the project and the gap between various design options targeting the same project. The process of design decomposition defined by Pennanen (2011) implies that it cannot even be predicted in the beginning of the planning stage of the construction project. In contrast, the design of the construction project should be the result of understanding customers' needs for the building usage and the resources available to actualize the project and deliver it to the end users. Thus, the design cannot be used to define the project scope in the early stage of project planning.

Construction cost estimation requires systematic and targeted approach, therefore the process has started to develop already in 1970s. The attempt to use statistical method such as regression analysis turned into realization that cost estimation in construction requires more input and methodology based on user experience. This led to the development of the tailored and custom-based cost estimation methods and tools.

The study is aimed to analyze the literature related to the construction costs estimation and existing methodologies, models and applications. The study will elaborate on target costing methodology in cost estimation and its application. Then study will analyze existing method of cost estimation based on premise requirements and facility costs currently used by NCC in other markets. Furthermore, the study will apply cost estimation methodology for NCC on the market of St. Petersburg, Russia market. And at last, the study will compare output result of the estimated model to the actual results of the case study and elaborate on the differences furnishing the research on further development.

1.2 Research problem

The research problem of the study is how to understand the need of the construction cost estimation methodology and how to apply the model for the market in St. Petersburg, Russia. The problem is described with three research questions and nine sub questions.

1. Research question 1: Why the construction costs estimation is vital for construction project planning? According to the existing studies, what are the main cost estimation methodologies applied by practitioners?

    a. What kind of approaches is there in cost estimation in construction?

    b. What models have been developed that assist in construction cost estimation?

    c. Why there is a need for tailored estimation models in construction based on target costing?

2. Research question 2: Using the methodology of cost estimation based on premises' requirements and costs, can the existing in NCC estimation model be implemented in St. Petersburg, Russia?

    a. What are the main construction project technical aspects that have to be included into the cost estimation?

    b. What is the price adjustment technique in the cost estimation?

3. Research question 3: Is the estimated model reliable for St. Petersburg, Russia?

    a. What is the difference between the cost estimation output and the actual project budget?

b. What is the efficient method of price adjustment for the model?

c. What are the main drawbacks of the model and which areas require further development?

1.3 The Purpose of the Study

The objective of the study is to provide an outlook on the construction cost estimation methodology based on premise-based requirements and costs and to implement the model for the St. Petersburg market. The aim of the study is to could be summarized into the following statements:

1. to analyze the current methodology of the cost estimation model used worldwide
2. to identify which parameters influence the estimated price of the construction project in St. Petersburg based on the space requirements and premise costs used in NCC
3. to incorporate price influencing parameters into the cost estimation model
4. to test the newly estimated model for usability
5. to provide further recommendations regarding cost estimation model implementation for NCC in St. Petersburg, Russia

1.4 The Scope and Structure of the Study

The field of the study is the cost estimation and target costing in new construction of the residential production. The definition of cost estimation and target costing will be taken from literature review, the calculations will based on the methodology developed by Haahtela and Kerkkänen 1991 in the publication “Space Requirements and Premise Costs” (Haahtela & Kerkkänen, 1991). The literature review will go through several approaches in cost estimation and describe cost estimation methods developed in the construction industry.

The study is aimed to look into the parameters that drive the price change of the construction project at its early stage of the planning phase. Furthermore, the study will attempt to conclude on the recommendations regarding price estimation of further projects where results could not be back tested right away.

The study is not going to elaborate on the subject of real estate development and building renovation while referring to the term of the construction costs. In its research, the study is going to focus on the new construction of residential housing.

In the quantitative analysis part of the research, the study will use the data provided by NCC and its’ subcontractors in St. Petersburg. Current project’s cost and parameters data will be used as a case study that has commenced in St. Petersburg, Russia and is currently in the production stage. The study will focus on the space requirements and premise costs for the building while constructing cost estimation for the project.

The research is divided into five chapters. The first chapter provides an introduction and a background for the study, where the motivation for the study is also explained. The second chapter includes theory and literature review that describes approaches in cost estimation and analyses three cost estimation models developed in the construction industry. Second chapter also defines target costing, and elaborates on construction cost estimation through a prism of preliminary information on premise space. Third chapter starts with theory application of cost estimation and target costing methodology and prepares the model for the case study analysis. Third chapter conducts a research for necessary parameters needed for the model to be valid in St. Petersburg, Russia. The third chapter is concluded with the model estimation based on the existing tool used in NCC. Fourth chapter will apply estimated model on a residential premise in St. Petersburg, Russia currently in production stage. The part will describe data collection method, estimation and testing procedures, and analysis of the results. The final chapter of the study will provide conclusions of the study regarding the obtained results, regarding reliability and validity, and advise on further development of the study.

1.5 Research Design

The research is designed according to the framework described by Creswell, J. W. 2003. The postpositive knowledge claim is used in the following study. The study will perform empirical observations in cost estimation calculations and will test those observations using case-study. Nevertheless the results founded during the study cannot be claimed as absolute, as further research in this area may provide stronger warrants than this study (Creswell, 2003, p. 7).

The research will use data provided by NCC in its research. The inquiry strategy of the study is experimental approach and surveys. By experimental approach, the study will assign parameters to certain conditions, and the survey will aim to collect the suitable data for model development.

The study will conduct construction cost estimation model based on the methodology described in Space Requirements and Premise Costs by Haahtela and Kerkkänen and the existing estimation tool used in NCC. The goal of the first estimation is to get the overview of the methodology as a whole and to be able to see how each parameter influences the total project cost. After the first estimation the model will be adapted to St. Petersburg market by changing the required parameters. During the adaptation process, the interviews will be conducted in order to obtain information regarding suitable parameters for the cost estimation model.

The validation strategy of the research will test the estimated model on a real case scenario and compare the estimated results to the actual figures. The estimation results will be analyzed for errors and weaknesses in calculation methods after which research will be concluded with the recommendation for further development.

2 Literature Review

2.1 Cost Estimation Definition

The term cost estimation in the construction business implies calculation of expected costs that are included in the production and a commissioning of the construction project. Moreover estimation engineers often include unexpected costs that may occur during production and commissioning of the planned project. The cost structure of the construction project implies material and labor costs according to the preliminary project plans and requirements for the building. Moreover, the project accounts different stakeholders involved in the process, so it is important to take into the account the price fluctuations of services and inflation. The cost estimation is defined according to the preliminary working drawings, plans or possible blueprints (DelPico, 2012, p. 1). As a process, the cost estimating is described as a technical function that is conducted in order to predict the total cost of the project in a given item with the use of the maximum available information and resources related to the project (Akintoye, 2000, p. 77). The Chartered Institute of Business defines estimating as "the technical process of predicting costs of construction" (Akintoye, 2000, p. 78). As we can see that both definitions contain term "prediction". The prediction factor can be understood that during the cost estimation process, the access to the information could be limited and the time is one of the main constraints during the cost estimating. Even though it is important to conduct estimation process as accurately as possible, it is rarely achievable to provide 100% accurate cost of the construction project at initial stage of the planning.

Another feature of the cost estimation is via certain methodologies is functions like a black box, meaning that it is difficult to understand certain elements of the estimation technique (Pennanen, et al., 2011). This results in justification difficulties whenever managers will try to present the calculation results to the decision makers.

2.2 Factors influencing cost estimation

After defining what is meant by cost estimation in construction it is important to understand what factors are influencing construction cost estimation. The cost estimation process is described as the process that requires fluent understanding of the market where the project is being executed. The main argument for that is that the project cost estimating practice requires initial information such as drawings, plans, possible blueprints, bills of quantities, etc (DelPico, 2012, p. 1) (Akintoye, 2000, p. 78). The reason why such information is required is for understanding the initial quantity of items needed for the construction project. Therefore, cost estimation practice requires certain knowledge regarding the past construction projects. In the estimation practice researched by Akintoye 1998, their manual includes the following factors to be focused on while estimating construction costs:

1. Completeness of drawings and its standard
2. Requires tolerance
3. Specification and requirements regarding the quality
4. Buildability
5. Amount of load bearing and non-load bearing structures

6. Extend of usage of information from previous construction projects
7. Information regarding design coordination and structural needs
8. Information regarding ground condition and foundation
9. Information regarding constraints on design and construction

Source: (The Chartered Institute of Building, 1997)

In most of the cases the source for the factors mentioned above is past experience from the construction projects. Although the historical data cannot be 100% reliable because every construction project is unique, plus in certain markets the price indices have to be updated more often than in other markets in order for cost estimation to be accurate.

Akintoye (1997) has conducted a research based on which are the factors that influence cost estimation procedure. In the study the author has conducted a survey questioning 200 randomly selected firms with the response rate of 42%. The aim of the study was to research for the current cost estimating practices used in the United Kingdom in 1997. The analysis used statistical method to obtain the results. The result of the study has shown that the most influential factors in cost estimating procedure are:

- Complexity of the project
- Construction scale and scope
- Market conditions
- Method of construction
- Site constraints
- Clients' financial position
- Buildability
- Location of the project

In total 24 factors have been subjected to the factor analysis that aimed to capture multidimensional relationship between them and rotation technique was used to make the interpretation easier and to scope down the results. The outcome of the grouping is shown in the table 1.

Table 1 Factor Analysis Grouping of Cost Estimating Factors

Influencing factors	Principal components						
	Factor 1 Project complexity	Factor 2 Technological requirements	Factor 3 Project information	Factor 4 Project team requirement	Factor 5 Contract requirements	Factor 6 Project duration	Factor 7 Market requirement
1	Expected project organization	Amount of specialist work	Quality of information and information flow	Capacity of design team	Type of client	Project duration	Location of project
2	Type of structure	Lead time (delivery and circumstances)	Availability and supplies of resources (labour & materials)	Project team experience on the type of construction	Client's financial standing	Anticipated frequency or extent of variations in construction requirements	Tender period and market condition
3	Site constraints (e.g. access and storage limitations)	Off/on-site operations sequence and limitations	Pre-contract design (extent of design/ construction interface)	Number of project team members	Procurement route and contractual arrangement		
4	Method of construction and construction technique	Buildability	Expertise of the consultants involved in the project				
5	Scale and scope of construction						
6	Complexity of design and construction						

Source: (Akintoye, 2000)

The study elaborates further on the discussion of the components included in the result which this study is not going to cover. The main idea of this part is to show which factors influence the cost estimating procedure according to the response of construction companies in the United Kingdom. Even though definition of the cost estimation process is mentioned as being technical process, the author suggests in approaching cost estimation from the point of knowledge and experience as well rather than purely calculation methodology (Akintoye, 2000, p. 86). In other words, it is justified to perform sensible amount of research while doing construction cost estimation process. Nevertheless, as time is one of the constraints during project planning phase, it is important to balance between research and technical process during the cost estimation process. Further in this study we will see how we succeeded to balance research and technical process in the case study part.

The case study conducted by Akintoye showed us factors that influence construction cost estimation process in the United Kingdom. Nevertheless, we cannot accept those factors as the ultimate truth for every cost estimation process in the construction, because it is limited to the market where the study has been conducted. On the other hand, it is useful to pay attention to those factors while doing cost estimation in the local market (St. Petersburg, Russia in the example of this study) in order to recognize more efficiently those factors that influence estimating practice on the market where the research is conducted. The study will address later the in the research the concept of the default building model where the necessary technical parameters are included by the default depending on the premise's location and function.

2.3 Approaches to Cost Estimation

Construction cost estimation techniques have been developed during 70's, which indicated the need and the demand for it. Traditionally the estimation was based on multiple regression modeling where the influence of the independent variables was measured on the dependent one. Although the regression model is not very efficient in describing non-linear relationship in regards to construction cost estimation because the relationship between the variables is multidimensional and results in multiple inputs and outputs (Kim, et al., 2004, p. 1235). In 80's the new line of approach in cost estimation has been developed, the case-based reasoning. The major idea behind the case-based reasoning method was to implement knowledge and intelligence from previous cases rather than applying purely statistical methods. Case-based reasoning gave direction towards tailored software packages used by different companies in the industry to estimate preliminary construction costs. Instead of complex algorithms and regression analyses, the model concentrates on the past events that are relevant to the current case study (Kim, et al., 2004, p. 1237). Thus, the calculation's focus is more on premise and space requirements rather than on separate independent variables and their influence on the dependent ones.

While case-based reasoning opens different perspective of cost targeting in construction, it also brings challenges for decision making in the sense of which cost calculation methodology should be applied how to present calculation results in a sensible way. There are multiple solutions on the market in the form of building information models (BIMs) for example DProfiler™, which output you estimated project costs based on the input according to the requirements for the building (Beck Technology Ltd, 2012). Also target costing information modeling incorporates construction parameters' data and provides decision making with the information on the approximate project cost. For example one widely used methodology in Finland has been developed by Haahtela Group (Pennanen, et al., 2011, p. 52). Nevertheless, regardless of the method of data presentation, the key thing of the cost estimation methodology is how efficiently it incorporates customers' wants and, space requirements, and premise costs into logical and clear presentation.

Before going into details on the target costing, the study will go through existing cost estimation modeling techniques and its application. First of all, the study will look into the literature that describes basic theories of probabilistic approach estimation method and how estimation model can be understood mathematically. Afterwards, the section will cover parametric methodology that is based on the regression analysis, neural network estimating technique and case-based reasoning method. The reason for describing probabilistic and mathematical perspectives is to give a quantitative background for the cost estimation in construction. The purpose of methods' comparison is to brief into more methodological perspective on construction cost estimation and to outline to which method will be paid more attention in this study and why.

2.3.1 Probabilistic approach

Companies use probabilistic cost estimation in order to assess risks related to the project during the initial stage. In practice it means that this method allows estimation engineers to create a range of possible project costs in order to evaluate the correlation of project cost and riskiness. The main usage of probabilistic cost estimation is in simulating the cost structure of the project. The simulation results in determination of virtual life-cycle cost of the project. The result is achieved by initial information input of parameters and its values by cost estimation engineers. The main gap of the probabilistic cost estimation and its application during the simulation process is the lack of insight on the long-term perspective as the approach concentrates on the present value of the of the parameters involved in the construction current project (Chou, 2011, p. 708).

Touran (1993) presents another application of probabilistic cost estimation where the total project cost is presented as a cumulative distribution function (Touran, 1993, p. 58). This means that the sum of cost components are incorporated and distributed into the probabilistic estimate. Afterwards it is added to the fixed components and derives to the total estimated project cost (Touran, 1993, p. 59). The result is the model of cumulative distribution function of the components that results in total project cost estimation. The author elaborates in his research on major advantages and practical difficulties of the estimated cost calculation during the usage of the method.

2.3.2 Mathematical perspective of cost estimation

This study is labeled as quantitative, although the research will not refer to complex mathematical or financial formulas during the literature review and the case study analysis, because there is no need for it. It is justified that the cost estimation technique that is more applicable to our case study is target costing and is based more on taking into an account suitable data rather than applying complex mathematical formulas to achieve valid results. It means that the resources dedicated for suitable data research play more significant role compared to creating complex mathematical solutions.

Mathematical method which is widely used in the construction, is a bottom-up approach which implies that costs are indirectly related to a construction project are fixed (Chou, 2011, p. 711). Therefore an author furnishes the research with the following basic formula for calculating total project cost (TPC):

$$TPC = \sum_{j=1}^{n} ItemCost_j$$

Where:

- *TPC* is Total Project Cost
- $ItemCost_j$ is the cost of the *j*th work item
- *n* is the number of work items in the project

Source: (Chou, 2011)

From the formula above we can conclude that construction cost estimation is not complicated from mathematics point of view. Nevertheless, certain studies elaborate further on the development of the cost calculation method in mathematical perspective. For example, Chou (2011) in the same study presents the following formula that accounts amount and price of the quantity separately, which is used for tendering phase in the construction project. The same research develops into the presentation of proportion to total project cost by accounting principal work items in order to increase efficiency (Chou, 2011, p. 712). This means that the sum of the work items is viewed as a proportional amount to the total project cost instead of just providing a summed amount of cost items relevant for the project. The study will furnish the research with the practical implementation of the formula by Chou (2011) in the model estimation section.

From the mathematical point of view, the cost estimation modeling is not complicated to understand. Nevertheless, it does not make the estimation process a trivial research problem. The mathematical perspective implies that the accuracy of cost estimation depends more on the quality of the data inputted rather than on the calculation formula.

2.4 Cost estimation models

To narrow the area of cost estimation in construction, we shift from the approach into the methodology and modeling. There are different methodologies that practitioners use. This study will discuss statistical method that includes regression analysis, neural networks approach which includes artificial intelligence, and case-based reasoning which will be narrowed towards the target costing method.

Before going into models, there are several methods of cost estimation. Parametric method which implies the usage of knowledge of certain physical characteristics and parameters related to the project (Duverlie & Castelain, 1999, p. 895). Case base reasoning method is defined as method that uses the solution from past experience regarding the project to target the current problem (Duverlie & Castelain, 1999, p. 897). Duverlie in his research compares those methods with the use of case studies of construction cost estimation at the initial planning stage of the project. Both of parametric and case-based reasoning methods can be applied into different tailored-for-market models. The parametric method has an advantage of being easy to use and apply to the certain project, although the results are handled via "black box" modeling, meaning that they are hard to verify. The case-based reasoning method has a better capacity of accepting unknown information and to look at it through the scope of the new project, which can result in more precise cost estimation (Duverlie & Castelain, 1999, p. 905).

2.4.1 Multiple regression model

Multiple regression analysis is represented in the form of the following formula

$$Y = C + b_1X_1 + b_2X_2 + \cdots + b_nX_n$$

Where:

- Y = total estimated cost
- C = constant
- $X1$, $X2$, Xn are the relevant variables that influence in estimation total cost
- b = coefficients that are estimated via the regression analysis.

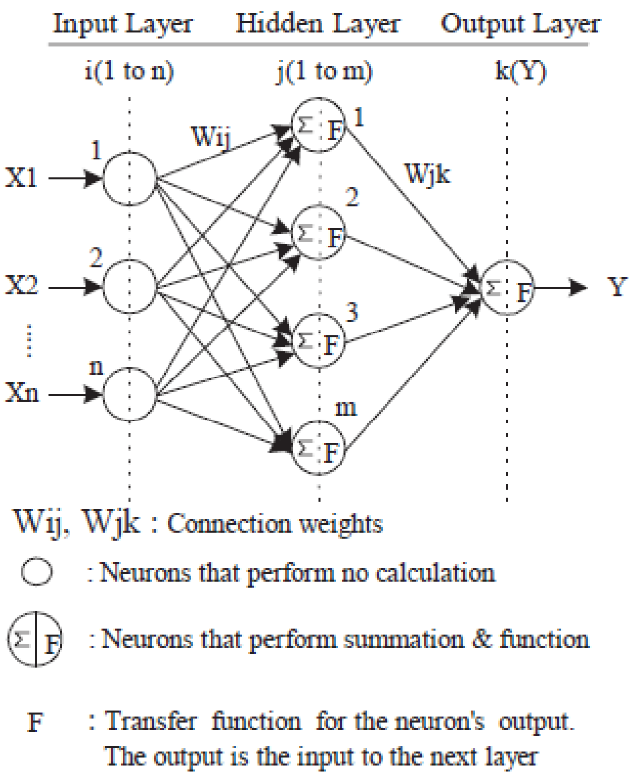
Source: (Kim, 2004)

The main function of the regression model is to measure the influence of independent variables of (X) on the dependent variable of (Y). In practice, regression model measures how significant price is influenced by variables. One practical way to conduct regression analysis is with the help of IBM Statistical Package for Social Sciences software (IBM Corporation, 2013). The limitation of the method is that it does not take into account past experience, which is vital in construction cost estimation and will be explained why later in the target costing section.

2.4.2 Neural network model

Neural network model includes artificial intelligence factor which functions as the "human brain". The method is designed as a network of input sets. The variables are inputted into the first layer, then they are estimated and correlated in the hidden layer against each other, and then the output is produced in the output layer. The diagram visualizing the neural network architecture is presented in the figure 1.

Figure 1 Neural Network Architecture



Source: (Kim, 2004)

The term neuron implies to the artificial brain cells that advance from project to project. Therefore, the methodology is efficient when the knowledge database is properly maintained and is developed with the new knowledge. The most challenging and time-consuming process, due to the trial and error estimation procedure, is the determining the amount of neurons in the hidden layer (Kim, et al., 2004, p. 1236). One of the practical applications of neural network method is the program named NeuroShell2™ developed by Ward Systems Group Inc. (Ward Systems Group, Inc., 2013). The process implemented by Ward Systems Group uses learning algorithm from the historical events, therefore with every case in theory it should diminish the total error between estimated and actual cost. Another practical application of neural network method in the cost estimation in construction is presented by Adeli and Wu (1998) that use regularization theory for increasing the efficiency of the learning process of the neural network method. The way of increasing efficiency of the learning process is actualized in minimizing the error function before estimating the model (Adeli & Wu, 1998, p. 91). Authors benchmark neural network method against regression analysis and point out several advantages over the regression analysis when estimating costs in construction.

2.4.3 Case-based Reasoning Model

The third model discussed in this study is case-based reasoning model. The main feature of the model is that it is based on the logic gained from the previous projects and cases. The model can sound similar to the neural network model as it also accumulates historical knowledge into model's learning process. But the main difference is that neural network model lacks the ability to learn "on the spot", meaning that it lacks an expertise when the area or domain is totally inexperienced (An, et al., 2007, p. 2573). Case-based reasoning model is based on the experience derived from the memory of the past events, and at the same time, not being limited to the current expert systems involved in the cost estimation. Kim (2004) describes case-based reasoning in the following steps:

- Observation of key attributes describing the problem
- Identification of those attributes from the previous problem
- Predicting new problem's direction

The main advantage of the case-based reasoning is that it incorporates human reasoning into the cost estimation calculations, which has a potential in providing the management with the more precise cost estimate than uncontrolled output from regression analysis and neural network models.

In practice, the case-based reasoning model is implemented in different areas of construction, for example in design and cost estimation. The model is an efficient tool for managers and cost estimation engineers in identifying estimated cost of new projects, nevertheless An (2007) points out in his research that it is challenging to implement the proper weights of the parameters of cost estimation of new projects (An, et al., 2007, p. 2577).

This study has briefly analyzed three different cost estimation models pointing out its main features. Next is to concentrate on case-based reasoning approach using the target costing methodology that has been originally developed for the use by Japanese automotive industry. It has also been successfully implemented in Finnish construction sector in 1980' (Pennanen, et al., 2005, p. 2). As mentioned in previous chapters, there are different applications of cost estimation methodologies presented by Ward Systems Group, Adeli and Wu (1998), and Duverlie (1999). The reason for choosing to elaborate on target costing methodology is that it defines the basis for the current construction cost estimation in NCC. Also, the theory of the target costing approaches clients' functional needs and drives project cost and design according to them (Pennanen, et al., 2005, p. 2), making this methodology a linking chain between clients who want the best quality for the money they pay and project managers who want the most cost efficient solutions.

2.5 Definition of Target Costing in Construction

Cost estimating of the construction project is the driver towards profit planning of the project. The main objective of the target costing is to justify the design process instead of calculating project costs according or after the design process is completed. Therefore target costing can be defined as a "range of techniques and methods applied as a part of a cost management" (Zimina, et al., 2012, p. 383). In his research, Zimina refers target costing to the traditional cost management in manufacturing. Nevertheless, the author elaborates on the term and adopts it for the construction industry by defining target value design.

Target costing can be understood as a method needed only for cost estimation, e. g. for the initial planning stage of the project. Nevertheless the philosophy of the target costing is described as win-win technique used by companies in long-term business planning (Zimina, et al., 2012, p. 386). This means that the target costing is an important factor in the whole project life cycle.

Target costing is a budgeting at the early stage of the construction project and is performed by cost calculation engineers. In the scope of construction project, the target costing is establishment of things necessary to be paid for. In practice the process is called as tendering where client secures the contract and subcontractor secures the work. From both sides cost estimates are presented, although rarely those figures are the same. The key purpose of the target costing is to end up with the preliminary project design towards the allocated preliminary budget, whereas simple cost calculation implies counting how much different design options will cost for the company. According to National Economic Development office, the target cost contract "specifies a best estimate of the cost of the work to be carried out..." (Zimina, et al., 2012, p. 386).

One of the practical implications of the target costing has resulted in 30% savings during the construction of large-scale oil and gas platform in 1996 compared to the earlier more similar projects. Unfortunately target costing has not been widely popular cost estimation methodology among market players worldwide. Nevertheless there are examples of few positive adaptations of target costing methodology, one of which is successful adaptation example in the Finnish market (Zimina, et al., 2012, p. 387). In Finland, Haahtela Research group has succeeded in theory implementation of the target costing. Their tool of workplace planning is based on research of client functions and physical planning and their steering methodology. The steering process leads to the preliminary design of the construction project by combining requirements and stakeholders' need and commitment for space (Pennanen, et al., 2005, p. 2).

2.6 Target costing process

In order to understand how cost targeting leads to design, it is important to understand steps of complex design idea conversion into the doable detailed design solution. Study mentions earlier that it is impossible to predict the exact project design at its early planning stage, it becomes clearer only when the time passes and planners know more about the approximate tender costs for the related project. As the time is a constraint and cost estimating engineers need to know as much information as possible in the planning stage, the different approach has to be developed.

According to Pennanen, Ballard, and Haahtela (2011), the design starts with understanding future customers' activities and project integration with the environment (urban planning). The building cost is the aggregate result of component stage and shape and connections stage. The component stage implies the total cost of necessary component quantities for the project. Shape and connections stage determines distribution of those quantities. The philosophy behind target costing is to decrease the gap between different design perspectives from the project cost point of view (Pennanen, et al., 2011, p. 54).

Tanaka suggests the following breakdown of target costing process:

4. Design requirements summarized by product definition
    a. Product's concept and mission
    b. Specifications of the products performance
    c. Product target costs
5. Design requirements summarized by concept design
    a. Formulation of the main functional areas
    b. Assigning of target costs to the main functional areas
    c. Performing a rough cost estimate to see whether the concept fits the target cost

Source: (Pennanen, et al. ,2011)

Pennanen (2005) describes target costing principles as following:

- Define functional criteria
- Determine target cost
- Design to the target

Source: (Pennanen et al. 2005)

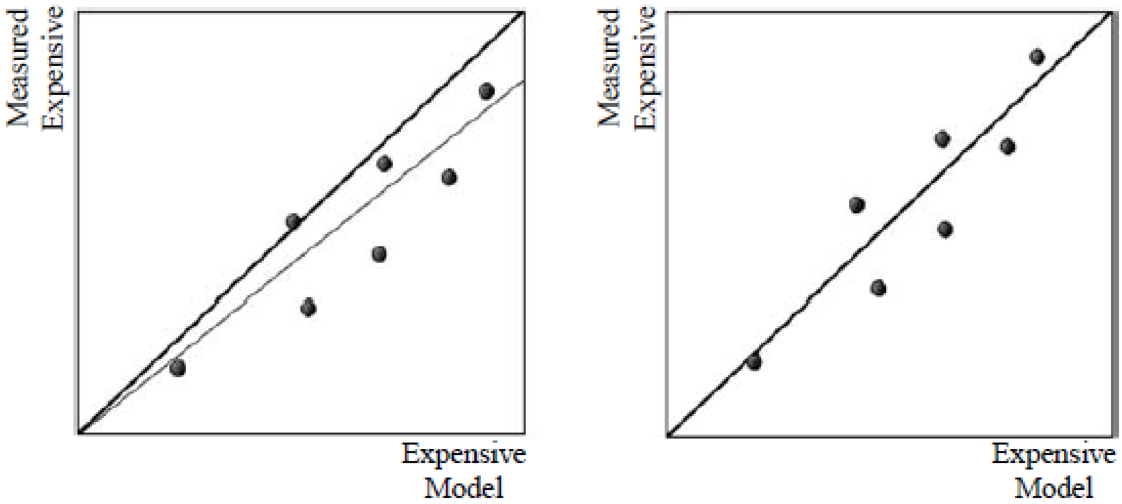
2.7 Component-level target costing

"A good design is made up of design parameters that result in the independence of functional requirements from each other" – quote from Nam Suh's independence axiom (Pennanen, et al., 2011, p. 55). This statement well describes component-level costing, which means that cost estimation process is broken down to the level of each parameter. In practice it means, for example, the type and the amount of beams, slabs, foundation, columns for elevator modeling depends on the usage frequency and the waiting times planned for the elevator. Component-level target costing is driven by customers' demands, as the whole process of target costing. In practice building information model (BIM) systems fulfill the role of delivering message using customers' language instead of designers one (Pennanen, et al., 2011, p. 55). As the customers' requirements are unique, purely statistical methods are not the most efficient in cost estimation, because historical data might disturb the learning process by shifting the focus from current parameters influencing the construction costs. Instead, using the component-level target costing, the model is constructed from the building components (reference database) that fit current customer requirements. As the result, the cost estimation is presented as the priced quantity required for the project based on the references from the market data (Pennanen, et al., 2011, p. 55). The statistical method uses the result of correlation of historical data instead of references from the market data, thus may become less valid for cost estimation of a specific project that uses different components compared to the historical parameters.

2.8 Project-level target costing

When we speak about target costing, we also imply that the cost estimation refers to the total life cycle cost of the project. The limitation of the component-level method is that it takes into account only components related to the project in its cost structure. Nevertheless, the construction project involves human labor during the planning and production process and also market fluctuations. The concept behind the project-level target costing is to adjust to the reasonable market cost level via black box method. We mentioned black box earlier in this study. Black box implies that its mechanism is unknown or unnecessary to be known. This means that the configuration of the black box is not important, but the information in the black box has to be updated during certain period of time. This method allows measuring clients' requirements against target costs and then comparing the results to market information regarding component costs and tenders (Pennanen, et al., 2011, p. 56). If there is a strong correlation between estimated costs and tender costs, then the model shows the direct relationship of expensiveness – if the estimated model is expensive, then the project will be expensive in reality. Figure 2 demonstrates the relationship between measured and market expensiveness and adjusts the model according to the market information. The figure shows the transition from modeled into the target costing client requirements towards the market costs and tenders.

Figure 2 Adjusted BIM to Market Costs



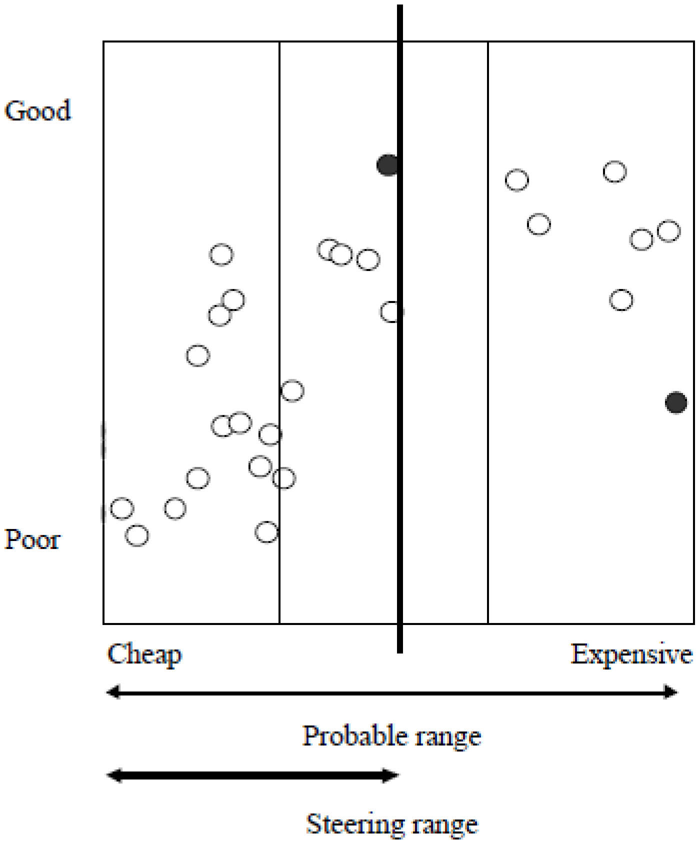
Source: (Pennanen, et al. 2011)

Project-level costing gives clearer overall picture of the project taking into the account the total life cycle cost. Nevertheless, it provides managers with several different options for the design for the project based on the target cost.

2.9 Design steering in target costing

Project-level costing takes into account the whole life cycle cost of the project which is vital for decision makers, but as a result, it ends up with several design options. Design steering methodology helps pick the most fitted design solution for the project based on the cost structure and requirements from clients. Note that the most fitted does not imply that it’s the cheapest one. The idea is not to provide the manager with the cheapest solution, but with the solution that will fulfill the client requirements and will be within the planned target cost and be identified as the most efficient solution. Pennanen and Ballard (2011) measured the correlation between project cost and quality to show that the optimal solution is not the cheapest or the most expensive one. The approach is from the cost range of view, or to be more precise, from reasonable cost range point of view. This means that certain reasonable cost range always suggests several design options. The study by Pennanen *et al.* (2011) shows that correlation between project cost and quality of the construction is minimal.

Figure 3 Correlation of Cost and Quality



Source: (Pennanen, et al. 2011)

The reason for the low correlation between cost and quality is that the quality is correlated more with artistic and creative factors of the designer rather than the cost of the materials to be used in the project (Pennanen, et al., 2011, p. 58). Therefore authors define a steering range for the design of the construction project. Steering range for the design is the range that narrows down design possibilities suitable based on the client and target cost requirements without sacrificing the added value from the architectural perspective (Pennanen, et al., 2011, p. 58). This means that when managers decided what will be the target cost of the certain project, this variable becomes fixed, whereas quality is the variable that is managed by steering design methodology and helps management in achieving the most suitable design option for the underlying project. In the figure 3 two highlighted dots represent the suitable projects according to the design. With the help of the steering range we can exclude the more expensive project as it does not fit the required steering range.

Looking at the life cycle cost of the project, we understand that estimated cost is only the part of the whole picture. Regardless of understanding that the project design solutions at the early stage of the project planning does not give the whole picture regarding the life cycle cost, it is still necessary part of the cost estimation process during the planning stage. After the design steering concept presented with the design solutions, it is necessary to choose the design and benchmark it against necessary parameters. Computer-aided design (CAD) systems are useful during that step in order to more detailed information concerning the project. Pennanen *et al.* (2011) suggests “defending champion” technique to choose the most suitable design solution. This technique means that one possible design solution is the correct one unless the designer finds and proves certain components to be contradicting with the original design concept (Pennanen, et al., 2011, p. 58). We know that it is not possible to measure all of the components at the early planning stage of the project, therefore the quantity will be benchmarked based on component-level technique discussed earlier. Therefore if the design concept is different from the target costing, then it is because the designer decided so. In other words, the design concept is based on the designer's decision and can vary accordingly, whereas the target cost is a fixed figure estimated by cost-estimation engineers. The "defending champion" technique provides the connection between CAD and target costing model on which is the most suitable design solution. This aims to achieve a mutual understanding between designers and decision makers regarding the project design.

2.10 Applying Target Costing in Cost Estimation

Previous chapters have identified the reason why construction companies use target costing methodology during the planning phase of the project. The next part will elaborate on how the methodology has been applied. When looking at the practical implementation of the target costing methodology, it is important to understand both sides – clients and project designers. Project designer tends to concentrate on each detail of the building in order to know what he has to plan, whereas client is not interested in diving into details of which kind of building blocks or columns are going to be used during the construction. Client is interested in certain functional space that fits his needs. As each building, whether it is residential or office one, is unique, target costing does not apply one building type as a template for every project, it approaches client functionality in each project separately as a complex problem (Pennanen, et al., 2005, p. 5).

In order for target costing methodology to be valid, it has to be related to customers' needs and tested with the market information. From the cost-estimation engineer perspective it means that the construction cost data is up to date and from the designer's perspective, there is an understanding of what customer needs and wants. Haahtela Group suggests the following formula for the application:

Client's requirements on the room and possible distribution of elements
+ use of resources connected to running costs (energy, cleaning, etc) =
Target Costing Application

With the help of the market information, the end result is application of design where each component satisfies one functional requirement. This being accomplished, it is easier for engineers and managers to understand what component serves what function avoiding unnecessary complication (Pennanen, et al., 2005, p. 8).

Haahtela Group provides the following table as an example of the model implementation:

Table 2 Space Quantification Example

Quantification Factor	Description	Example of Education Institution
The total volume of the sector.	No. of Customers or Products.	Two hundred design students.
The activity bill programmed for the sector.	Core Activities Supporting Activities	Teaching & Research. Administrative activities. Dining.
The temporal strain of functions and goals for the use of time in the space i.e. utilization degree.	Temporal Strain. Operating Degree.	Teaching Design Theory 4 credits, 30 h/ credit equals 120 h temporal strain/ student during 3 years. Facility management sets a 75 % utilization degree target for learning environment spaces.
The people working and the geometrics of the objects to be placed in the space.	Each function requires space expressed as a performance result.	Lecturing requires 10sq. Meters of lecture area. Students require standard seating and 1,2 sq. meter workspace. Material shelving require…
Regulations.	Regulatory society defines the quantification of space.	A basketball court have certain dimensions

Source: (Pennanen, 2005)

As we notice that the input is a client activity of an example building. The outcome is how the space is going to be utilized. This allows managers to plan what activities will be included in the project, when they are going to use it, what are the minimum requirements for certain space and what are the resources allocated for it (Pennanen, et al., 2005, p. 10).

2.11 Concept Analysis Application

Another application example of cost estimation methodology is a research conducted by Saari (2008) where the author compares four apartment building design concepts in Nordic area based on the calculation method of target costing. Table below presents the target cost calculation for a residential project.

Table 3 Target Cost Calculation

Space	Size sq. m	Number	Area sq. m	Unit cost €/sq. m	Costs €
Dwellings					
Two rooms and kitchen	46	8	368	1,289	474,000
Three rooms and kitchen	69	8	552	1,189	656,000
Four rooms and kitchen	93	8	744	1,087	809,000
Common spaces					
Storage	69	1	69	807	56,000
Stairs, corridors and technical spaces					
Stairs	1	266	266	1,285	342,000
Technical room	2	21	42	898	38,000

Source: (Saari, 2008)

From the table above we can see the target costing methodology applied on practice. The idea is to of the method is to create a profile of building which is estimated. In the following example we understand that there can be as many design options as there are architects according to the given space profile. Therefore management will have to decide on the project considering proposed design space efficiency, cost level, and how it satisfies customers' requirements.

Table 4 Building Element Estimate Calculation

Building element estimate		Amount	Unit	€/unit	€
1222	*Load-bearing walls* – concrete wall 180 mm, steel 6 kg/sq. m	1,126	sq. m	75	84,450
1225	*Ground slabs* – concrete slabs 60 mm, mineral wool	391	sq. m	23	8,993
1226	*Slabs* – concrete slab 220 mm, steel 15 kg/sq. m	3,519	sq. m	56	197,064

Source: (Saari, 2008)

In the table 4 we can see the estimate of the building elements for the example project. This is the part of the cost estimate engineer to build the estimation according to the project profile. We can notice that the calculation does not include any algebraic formulas, on the contrary, it is more of a straightforward technique of addition and multiplication as shown via the formula developed by Haahtela Group.

In its paper, Saari (2008) presented the study of comparing four residential projects in Northern Europe. Projects presented four different design options based on the target costing calculation and the most efficient was chosen based on the scores from efficiency and cost measures (Saari, 2008, p. 31).

Until now probably one of the questions that might come up is how the target costing method should be used and why companies should be bothered about it if anyway the end result is multiple design possibilities. The most important fact that should be noticed when thinking about the target costing is that it is only the tool for the managers and not any substitute of a decision making process. The idea of the target costing method is to make the decision making process more transparent and easy and not in any case create a substitute for it. Another important factor of the target costing is an understanding that it is an estimation which is done by cost estimating engineers. Therefore this process implies the human factor which yields space for mistakes. In other words target costing is not a fortune telling machine. It is an organizational tool that helps in clarifying the data used for estimating costs for the construction project. That being said, the target costing is vital and efficient tool for cost estimation, although it is important for managers and cost-estimating engineers to understand how they are using it and how did they get results using target costing methodology.

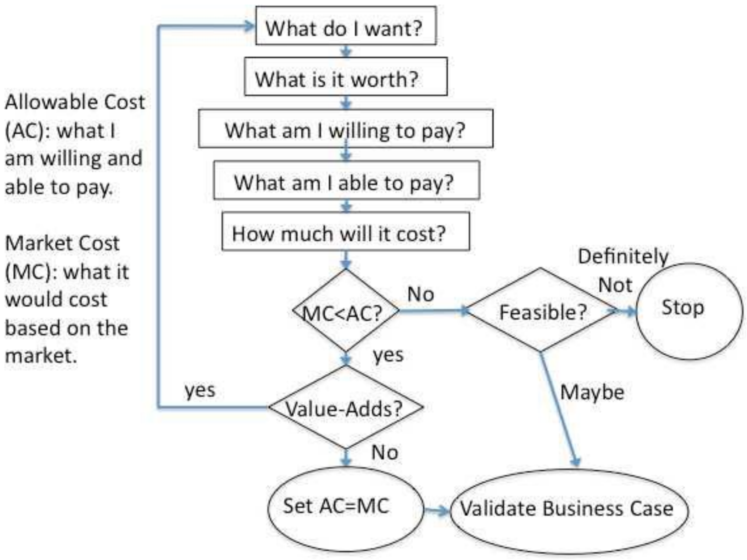
2.12 Budgeting

Ballard elaborates on that theme by looking at the target costing of the project from the customers' perspective and from the product's nature perspective. This study has mentioned that construction projects are unique because they have a target group of customers. This creates an additional challenge for the managers – the project should be sufficiently funded in order to provide its function and it should be cost efficient. These two elements may cause a tension in decision making process between managers (Ballard, 2012, p. 762). Ballard in his paper divides budgeting into two categories:

- Target costs
- Allowable costs

The target cost implies the total cost of the project is based on the balance between the added value desired by the customer and the price of the components needed for the project execution. Whereas the allowable costs are based more on how much client is willing to spend on the project and then the costs are benchmarked against the market costs.

Figure 4 Determining the Project Budget

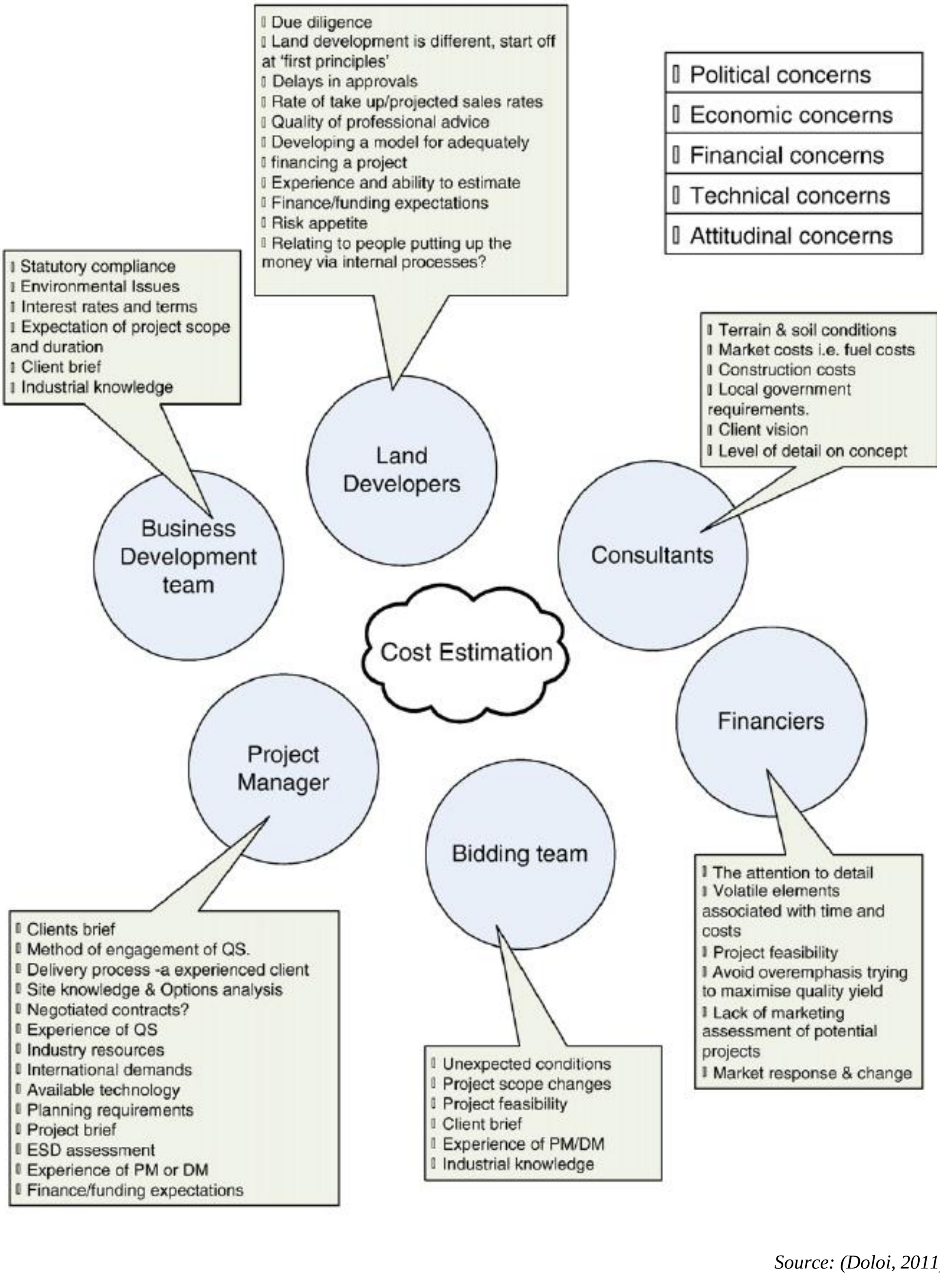


Source: (Ballard, 2012)

Ballard shows illustrative way in the figure 4 how to apply target costing in practice. The target costing is the tool for budgeting on the early stage of project planning. The goal of the budget is to identify the project cost based on the current market data and if customers are willing to pay the price for the project to be delivered. In other words, budget shows the project feasibility, where it is not achieved the project should be stopped (Ballard, 2012, p. 763).

From the previous paragraphs we understood that it is important to account the position of clients during the project budgeting. Target costing is a handy tool for cost estimation, nevertheless it is useless without the vital information regarding stakeholders' perspective. Understanding perspective of each stakeholder results in less probability of project cost overrun because usually extra margins are usually imposed by the end users on the delivered services. Of course there are other reasons of possible cost overrun like lack of practical knowledge of the estimators', lack of time for estimating procedure, poor documentation during tendering. In his research of understanding shareholders' perspective, Doloi (2011) has outlined the major reasons of cost overrun in projects from different industries and aimed to fill the missing knowledge gap during reference establishment in cost estimation process (Doloi, 2011, p. 623). In the figure below an author pictured the factors that influence project cost estimation and may lead to cost overrun.

Figure 5 Model of Cost Estimation at the Project Inception Stage



Source: (Doloi, 2011)

The model below shows factors that influence cost estimation at the initial stage of the project. The model is not limited to the construction industry only, therefore it can lack certain specialties applicable to the area. The figure presents each group of stakeholders (blue circle) that influence cost estimation and budgeting. The green box connected to each circle represents factors influencing the cost estimation procedure. The figure presents five categories of concerns that influence the project as a whole: political, economic, financial, and attitudinal. Doloi (2011) summarizes those categories against the stakeholders of the project. Cost overrun, being a problem during the project execution, creates a reason to use target costing method during the project planning stage. None of the authors claim target costing to be the "absolute cure for the itch", although it helps involved stakeholders by furnishing them with adequate and valuable references for decision making. This results in diminishing the knowledge gap during the initial phase of the project while conducting cost estimation procedure.

2.13 Building Information Modeling (BIM) Application in Target Costing

In the previous paragraphs we have done the literature review of the practical application of target costing in form of budgeting and understanding stakeholders' perspective on the estimated project. As mentioned before, target costing process is more than just a cost calculation. The study mentions Pennnanen's (2011) claim that the estimated cost is only one part of the estimated project. In practice it means that decision makers are interested in looking at the whole life cycle cost of the project. This is achieved by using building information modeling (BIM) in the construction market. This chapter will show how the usage of BIM assists in building data management and helps in cost estimation process. At the moment there are plenty of BIM software solutions in every region addressing different needs, but this study is only going to mention briefly about couple of researches conducted regarding the BIM in the construction area. While CAD is the approach towards design of the building BIM is the process to manage the information regarding the building in a consistent and reusable way (Lee, et al., 2006, p. 758).

Key feature of BIM is to represent building and its detailed parts in data environment (Azhar, et al., 2008, p. 3). BIM usage results in

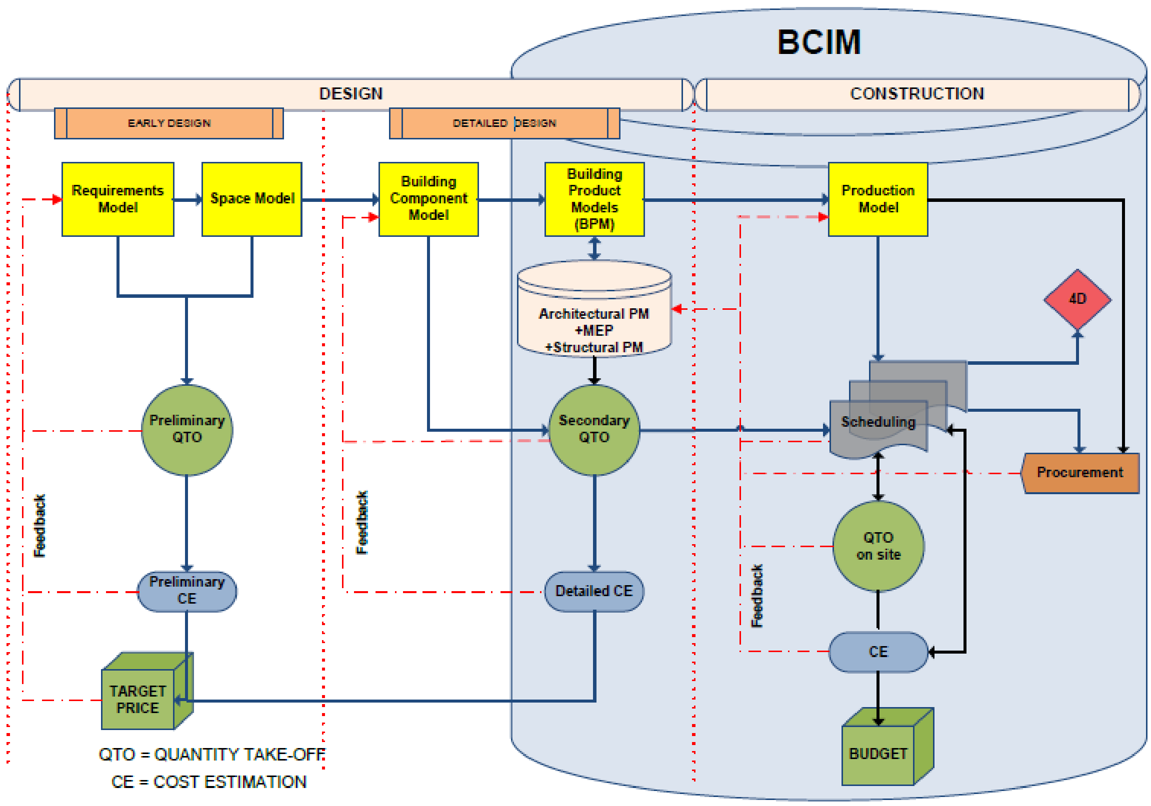
- More efficiently shared information
- Benchmarking and analyzing of different design options in a more efficient way
- Better understanding of project life cycle and its environmental performance
- Better analysis of proposals towards customers and stakeholders
- Data estimated for the building project can be used later for the facility management of the building

Azhar (2008) elaborates further on BIMs values and benefits for the players in the construction industry furnishing the research with the case study which is looked through the economical perspective. For example in the best case scenario the return on investment of using BIM solution in resulted in 39900% whereas the average ROI (return in investment) of the analyzed cases were 9486% (Azhar, et al., 2008, p. 9). In the end the author elaborates on economic incentives for BIM usage, nevertheless there are also certain risks that persist in using the modeling that are going to be discussed later in more details.

We have to understand that BIM is only the tool for the decision makers and not an automated method for decision making. Modeling helps stakeholders in accessing and managing the knowledge from the early development stage to the end of the process and retained afterwards. Howard (2007) has carried out a survey that forecasted that BIM system usage is planned to grow by 85% whereas manual design drafting and 2D CAD modeling is decreasing by 55% and 32% respectively (Howard & Björk, 2008, p. 272). The only downside of the BIM systems mentioned by authors is its lack of value for money from the point of view of certain property owners and construction companies (Howard & Björk, 2008, p. 279). BIM systems are useful and in some cases necessary tool for players on the property and construction market, but the main point is how one uses it to achieve maximum utility during the planning stage of the project.

BIM systems refer to the total project life cycle cost, therefore estimation is only one part of its function. Nevertheless as this study is concentrated on cost estimation, let's look closer how BIM can add value during quantity take-off procedure. To remind, quantity take-off is a process of detailed calculation the amount of components needed for project construction. It is vital part of the cost estimation process. BIM is presented by Firat (2010) as solution for faster and more efficient quantity take-off system. In the construction industry practitioners use mostly construction-concentrated BIMs, making it a Building Construction Information Model (BCIM). BCIM is defined as "dynamic and changeable library-based information model that uses commercial software to allow semi-automatic, partly interactive generation of design and production information…" (Firat, et al., 2010, p. 2). From this definition by Firat (2010) we can understand that the BCIM is the system that aims to generate design based on the input by cost engineers.

Figure 6 Quantity Take-off During the Project's Life Cycle



Source: (Firat, 2010)

The figure 6 shows the process flow of quantity take-off during the design and construction stages of the project. As we can notice, cost estimation is performed three times – preliminary, detailed and final. Preliminary cost estimation is the most important for this study, nevertheless this diagram shows that it is done without consideration of building components. This being said, detailed cost estimation conducted second time already takes into account building component and product models, therefore is more relevant as a cost estimation based on target costing. Looking at the figure 5, we can think of BCIM as an efficient tool for quantity take-off and followed by cost estimation. The area of BCIM application is market in blue on the graph. We can notice that the system absolutely requires initial information inputs from cost estimation engineers before it can output any design.

To summarize, BIM and BCIM systems are efficient practical application of target costing methodology. Looking at the literature, we can notice that there is no market domination of one player in the industry. That means that those solutions are more tailored for specific area rather than standardized globally. The important note to be carried out from this section is that those systems are only an application of the methodology, meaning that it only acts as a helping solution in organizing massive amount of data needed for project cost estimation. The accuracy and validity of data depends on the geographical market and inputs from cost estimation engineers. The data quality directly correlates with the accuracy of preliminary cost estimation. To be more precise, it is more vital to have a correct data inputted rather than latest BCIM system in use during the cost estimation procedure.

2.14 Risk

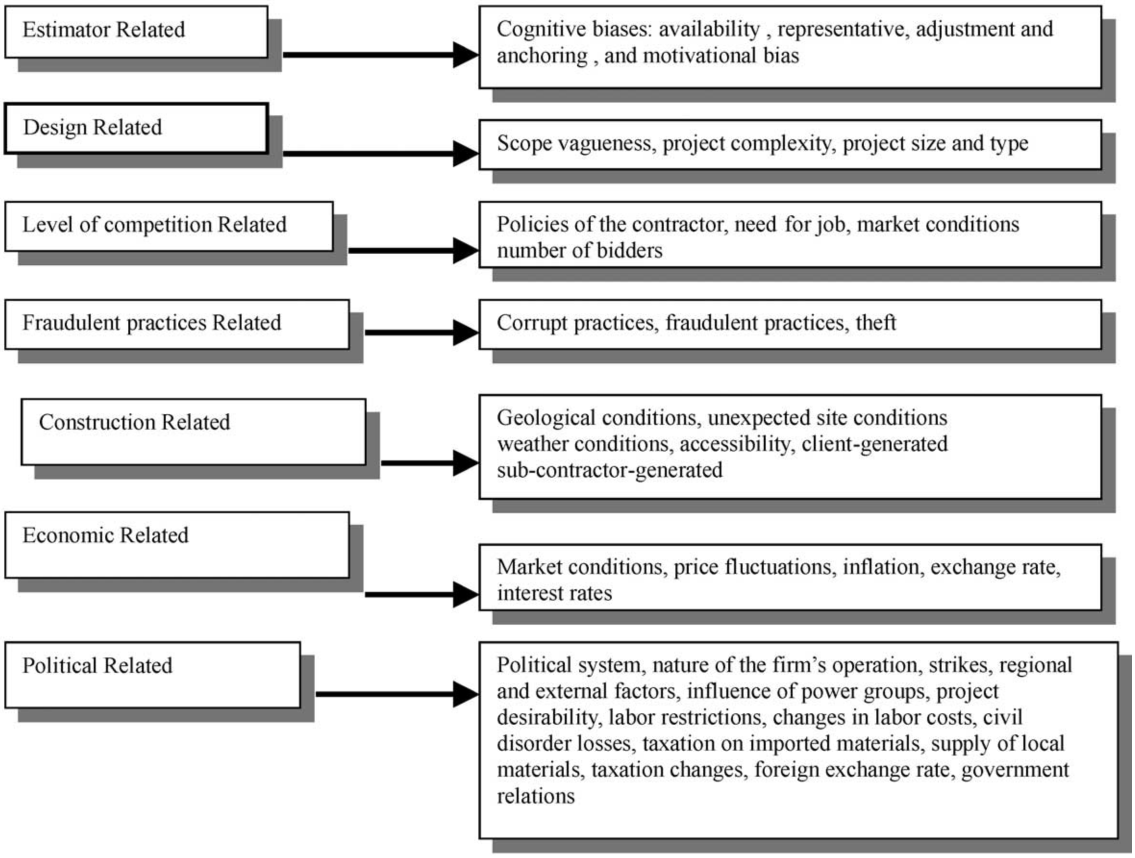
Measuring cost performance at the early stage of the project is a difficult and non-predictable process at times. Term estimation implies risk because the estimated cost can vary from the actual cost when the project is in the construction stage and cost estimation has been done on site. If we look at the long term planning of the project, there is a risk of inflation and inaccurate price indexation of components for the construction project. This study will identify risk in the construction and will briefly look at several approaches of risk management and will be finalized with the example of risk management application.

Baloi and Price (2003) refer to risk as a “chance of failure or the possibility of meeting danger or of suffering harm or loss”. In construction authors define risk as a probability of harmful event happening to the project (Baloi & Price, 2003, p. 262).

Many companies spend substantial amount of resources in understanding and attempting to mitigate the risk. Risk management is important because investment amounts into the construction projects are relatively lumpy, therefore companies prefer to invest in finding out about risks in advance rather than facing the fact of sudden extra expenditures. Risk understanding in terms of cost estimation requires understanding of the difference between preliminary cost estimation and final amount. That usually happens in discrepancy in tendering contracts. As construction projects involve multiple stakeholders, each relationship can be rated on its level of riskiness. The risk is also in the operations of the construction company itself. In most of the cases construction companies are the main contractors, therefore they are responsible for planning and preliminary cost calculation of the project. In that case, the risk may be realized in invariability and the need for adjustment after the tender process has been finalized.

For the risk mitigation it is important to understand that construction companies operate in the certain environment. That being said, Baloi and Price (2003) identify global risk factors affecting the project. The figure below represents the main groups of the risk factors.

Figure 7 Groups of Global Risk Factor

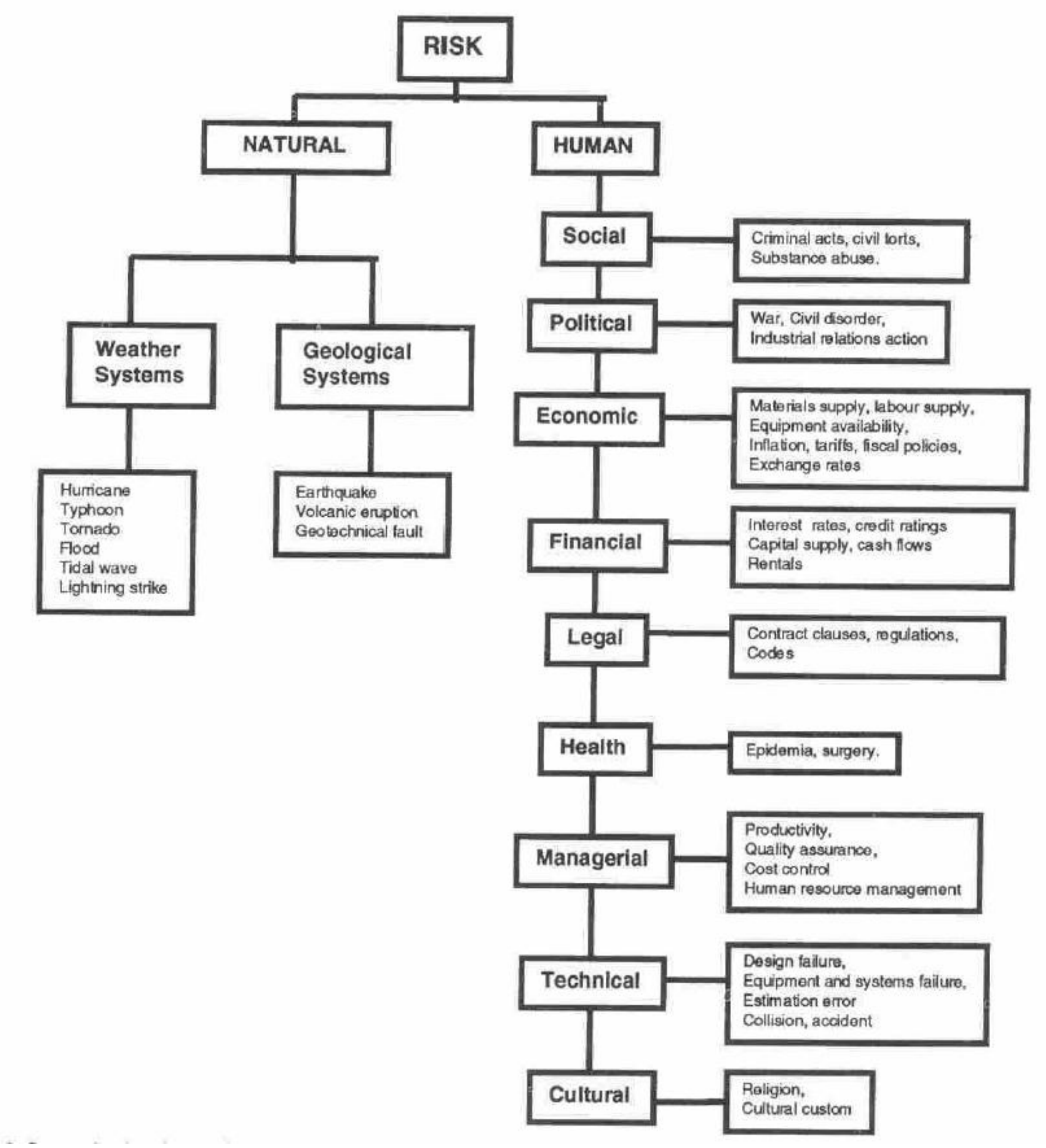


Source: (Baloi and Price, 2003)

The figure above is self-explanatory – it lists risk factors and describes them shortly. The question that practitioners worry about is how to manage those risks. Again, the question is about the knowledge one has regarding the data necessary for the construction project cost estimation. For example, we can obtain the latest prices for the components, although it is hard to account inflation, especially in more unstable markets. Therefore, the risk management depends on experience and persons judgment (Baloi & Price, 2003, p. 265). There are tools to assist managers in risk mitigation, but as in target costing procedure, they are only additional tools complementing the decision making.

Edwards (1998) in his research of reviewing literature on risk defines the term as "probability of adverse event during a stated period of time" (Edwards & Bowen, 1998, p. 339). During the application for the construction industry, the author as well categorizes the risk into categories similarly to Baloi and Price (2003). Though, Edwards (1998) divides risk into natural and human categories before elaborating on risk factors. Risk categorization can be found in figure 8.

Figure 8 Categorized Project and Construction Risks



Source: (Edwards 1998)

Comparing figure 7 and 8 we can notice certain similarities in understanding risk management. Authors analyze theory and aim to deliver the message what kind of factors are important to take into account while performing risk management. These risks are related not only to early planning phase, but also should be taken into the account during the whole life cost cycle of the project. Risk categorization assists managers and decision makers in risk identification and mitigation, but does not provide direct solution for diminishing the risk.

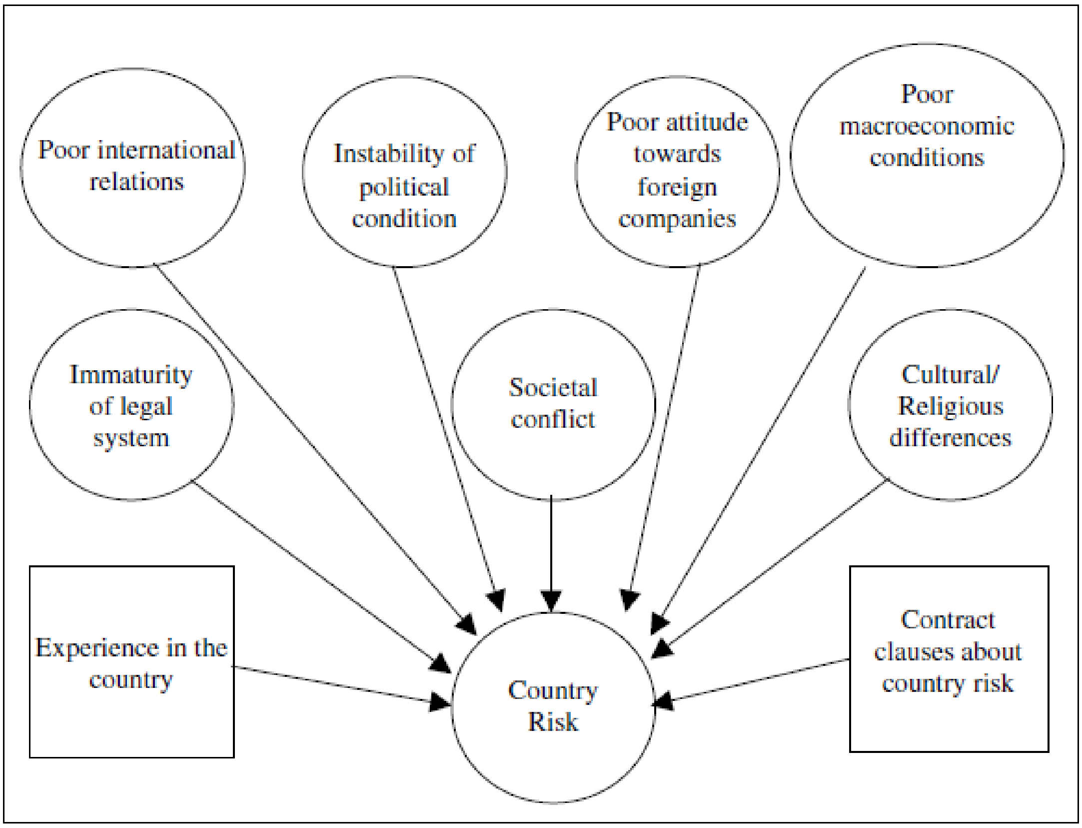
One of the practical implementations of risk management is presented by Dikmen (2007) in his research an author presents how fuzzy risk assessment rates cost overrun risk. Fuzzy logic implies that the reasoning is not as precise as in mathematical methods. One of the ways to apply fuzzy logic is to use IF – THEN rule. So, Dikmen proposes the following fuzzy risk assessment:

- Usage of influence diagrams
- Selection of membership function of each variable. For example variable is mapped between 0 and 1 on the scale of riskiness
- Usage of aggregation rules to capture experts' knowledge on risks and its influential factors. For example the usage of IF-THEN rules to measure how risk level changes under different scenarios
- Applying fuzzy rules into fuzzy cost overrun rating. For example the worst IF-THEN scenario means highest cost overrun rating.
- Determination of the project risk level based on risk on cost overrun rating.

Source: Dikmen et al. (2007)

Example of the application of the above methodology can be found in the figure 9.

Figure 9 Influence Diagram of the Country Risk



Source: (Dikmen et al. 2007)

The figure 9 represents where does the risks originates from. Looking at the factors that influence the risk, we can see that they cannot be measured or calculated mathematically. The logic behind fuzzy risk assessment in this case is when the company experience in the certain country increases, the country risk decreases (IF-THEN rule). If we compare two companies with different experience levels operating in the same country, we can assess that the one with the lower experience has higher risk in getting to cost overrun (Dikmen, et al., 2007, p. 498). The research by Dikmen (2007) continues on classification of factors influencing the risk and ends up in assessing results that provide the risk level of cost overrun of a project. The assessment is a useful tool for decision makers, nevertheless it can be rather subjective than objective, because the data is not calculated mathematically but is based on the historical experience of the analyzed market players.

Another application of risk management methodology is estimating using risk analysis (ERA). This application helps to affirm possible accidents and to identify uncertainties during project planning. By identifying uncertainties and contingencies at the early stage of project planning, it is possible to estimate them from the financial perspective. Uncertainties and contingencies refer to risk factors that ERA aims to realize and mitigate. Common practice of implementing risk financially is to add percentage allowance to the final cost of the components or works, but this method has its weaknesses. Mak and Picken (2000) present ERA as the method that identifies risks that are associated with the certain project. The method starts with identification of the risk-free scope of the project, in other words, the scope where the information is available and fully predictable. Only then, the method goes into risk identification and categorization (Mak & Picken, 2000, p. 130). Authors present details of the method and its calculations in the research. The main advantage of the methodology is that it is able to present cost estimation for the project plus capture contingencies and present them in financially understandable manner (Mak & Picken, 2000, p. 133). In other words, it assists management in estimating risk allowance for the project more precisely and creates environment for better accountability for the risk allowances.

2.15 Summary of the Literature Review

In the literature review we have outlined definitions of cost estimation in the scope of the construction industry together with different types of application in cost estimation in construction. The literature review aimed to answer the first research question by outlining why the estimation process is important and what are the current methodologies applies by construction industry practitioners. The study looked into the main approaches in cost estimation methodologies and which models have resulted based on those methodologies.

Another term that has been defined and looked into is target costing methodology. Literature review has described applications in target costing on the example of Finnish construction industry and the methodology developed by Haahtela Group. Literature review also identified only few examples of target costing application in the construction industry. According to Zimina (2012), the successful application of target costing has been registered in one case in United States, two cases in United Kingdom, and couple of cases in Finland. By application we mean that the theory was directly and deliberately applied in cost estimation process.

Literature review aimed to show the importance of target costing as a cost estimation methodology in the construction. Previous chapters aimed to also identify risks connected to cost estimation and target costing.

3 Model Estimation

This next part of the study will implemented case-based reasoning cost estimation method and the concept of target costing on the real-life example. The study will describe how NCC conceptualized the estimation technique into the working tool and what its role in the design management process of the company. Afterwards the estimation tool will be tested on the market of St. Petersburg, Russia.

3.1 Construction Cost Estimation in Residential Construction

The study has conducted literature review by describing cost estimation methodology and various techniques used in cost estimation process. The applicable method for the cost estimation in the case described in this study is case-based reasoning. To be more precise, the methodology is based on the target costing methodology aims to create design steering process throughout the whole project life cycle.

The target costing stands behind the application idea of construction cost estimation model in NCC. The target costing is useful in case of initial budget estimation of the construction project. The budgeting at the initial planning stage becomes an important tool during the whole design steering process, as it helps in understanding the project scope at the early phase of the project.

3.1.1 The Construction Cost Estimation Norms in Russian Federation

Russian Federation has a centralized system of construction cost estimation that uses the database provided by the federal pricing center. The cost estimation system is a more complex one than in Finland because Russia has different pricing categories depending on the customer for the general contractor. If the customer is a private corporation, general contractor has to estimate according to the database for private companies, and if the customer is a Russian government or a municipality, then the general contractor uses the database of discounted prices designed for government institutions (Feshchenko, 2014).

Price databases depend on the region of the construction project. Indexation of technical parameters is provided by Federal Pricing Center or Russian Federation (Federal Pricing Center of Russian Federation, 2014).

The practical implementation of cost estimation in Russia is done by two major market players: Gruppa Kompanij Grand and Wizardsoft. Both of those companies develop cost estimation software for Russian markets (Gruppa Kompanij Grand, 2014) (Wizardsoft Corporation, 2013).

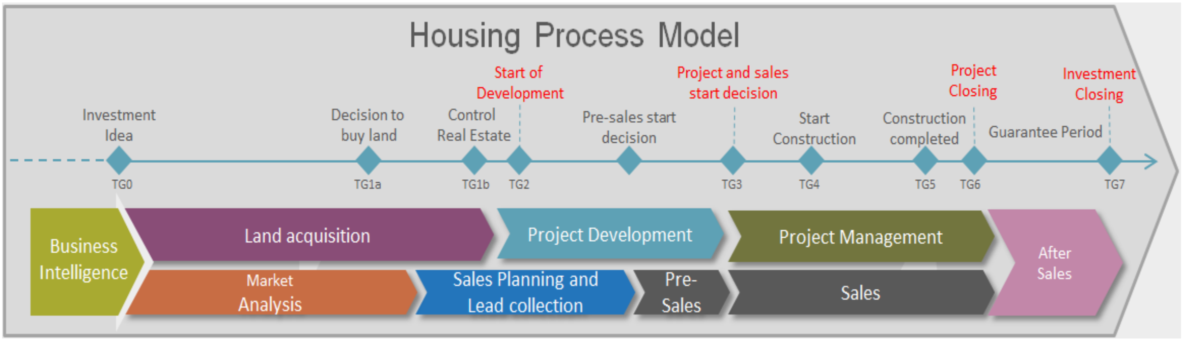
3.1.2 The Role of Cost Estimation in Design Management Process of NCC

In the literature review, the research has outlined that the construction cost estimation plays an important role during the project planning phase. Prior to elaborating practical role of the cost estimation, the study is going to describe design management process used for planning residential construction projects in NCC. The figure below describes management on the business area level.

The main goal of the design management process is to provide a framework for the design steering of the construction project. As mentioned in the literature review, the design becomes a discussion point in the very early phase of the project planning, therefore it stimulates managers and engineers to find solutions for optimal design solutions. Being a complex task, it requires systematic management process.

Thus, the justification for highlighting the cost estimation procedure in the design management process is based on the fact that construction professionals are required to estimate the total project cost during the plot acquisition and town planning phases (Boytsov, et al., 2013). Looking at the design management process, we can notice that those two stages influence the whole construction process and are major decisions made during those steps are not easily revertible. For example, if the plot is acquired towards the ownership, it becomes a lumpy asset. If the company will realize that the plot acquisition was not as potentially profitable as expected, its liquidation might become a financial burden for the company. During the town planning phase, the license acquirement is a time-consuming process where coordinal change of plans can be resource-consuming or not even possible. Therefore, it is important to back up decisions with the most correct information at the early stage of the project.

Figure 10 Housing Process Model



Source: (NCC Group)

The process shown in the figure 10 is represents general process model during in housing production in NCC. The housing process model is the guideline for the company managers for residential production. The points on the middle line represent the numbered toll gates or benchmarks project has to pass in order to succeed. The process model is clear representation what has to be done in order for a construction project to be actualized. The main issue of the research, therefore, is to indicate the importance of the cost estimation procedure in the project. According to the literature review, the cost estimation is done before the preliminary quantity take-off, which is the early design or planning stage of the construction project. In the housing process model, the cost estimation is made primarily before the toll gate 1A “decision to buy land” where the calculations show possible project scope and where it provides framework for the design group. While people might treat cost estimation procedure as a one-time process, some market players see the need to continuously adjust cost estimation results in order to estimate the total project cost as accurately as possible in the early planning phase. Thus, the cost estimation process becomes a systematic procedure which not only used for preliminary budgeting but also for the benchmarking project scope deviation during the design stage of the project. This results in the estimation process development through learning from historical events, which is the feature of case-based reasoning model.

Cost estimation plays an important role during the toll gate 0 and 1 in the housing process model. It gives project cost estimate for managers and guidance for design options. Nevertheless, the application of cost estimation is usually actualized in a certain framework with the help of the software. Each company has their own method of cost estimation application. One of the examples of the cost estimation application can be found in the table 3 and 4 in the literature review. The cost estimation tool used by NCC will be described in the next chapter in more details. Also, the cost estimation application is standardized for all the projects except some minor technical parameters that may differ depending on the construction project.

Based on that, it is logical to consider cost estimation application to be consistent throughout the planning and design phase. Thus, the cost estimation application brings value also during the design stages before the project start decision (toll gate 2 and 3). At this point the concern might arise whether the cost estimation adds value in the toll gates during the design stage. If the cost estimation process is conducted in the consistent matter, then the added value results in the ability to register possible changes to the project scope which came during the design stage. To be more precise, if the project scope has not been significantly modified, the cost estimation model creates reference data for cost estimation engineers in further estimation projects. The reason why the cost estimation is useful during the design stage is that the design is driven by target cost for the project and the target project cost is identified by cost estimation. Therefore if we have identified the target cost for the project during the planning stage (toll gate 0 and 1), there is no reason to seize referencing while adjusting calculation further during the design stage. On the contrary, it is beneficial to use figures of preliminary cost estimation of the construction project to know the approximate price level of elements possible included in the project price. Moreover after the cost estimation at the initial stage, project managers tend to consistently carry the information towards the design stage. This happens when the project is not following unified methodology of the design steering thus cost estimation is performed by many units separately causing waste of resources.

In order to understand where exactly implementation of the cost estimation is beneficial in NCC design management process, let’s look at the breakdown of the process model in the figure 11 below.

Figure 11 Design Management Process in NCC Housing Business Unit

Plot acquisition	Town planning	Management of utilities	Design	Preparation for production	Production	Completion and Commissioning	Maintenance
1. Plot Market Analysis	1. Data collection for town planning	1. Technical Conditions for Utilities	1. Technical Task for Design	1. Basic Plans for Production	1. Designer's supervision	1.Finishing of site	1.Guaranteed and Liabilities
2. Plot Acquisition Proposal	2.Town planning	2. Design for Utilities	2. Project Development	2.Management	2. Scheduling	2.Commissioning and Hand Over	2.Customer
3.Acquisition	3.Customer	3.Construction of Utilities	3.Design Documentation	3.Purchasing Plan	3.Management	3.Finance	
4. Customer			4. Customer	4. Finance	4. Finance	4. Post Analysis	
				5. Safety Plan	5. Procurement	Customer	
					6. Continuous Task Supervision		
					7. Safety		
					8. Customer		

Source: (NCC Housing, Russia)

The figure above shows the design steering process outline used on business unit level in NCC. The reason for referring to the design management process is to outline the optimal added value of the cost estimation methodology for the whole process. Also we have to keep in mind that each step is in the design management process is sequential, therefore stages cannot be viewed as individual occasions. This means that if one stage will be accomplished successfully, its success influences other stages of the whole design process, which justifies the motivation for further development of estimation process. That being said, the developed cost estimation methodology not only influences one specific stage, but also the whole design management process.

Construction planning process in Russia differs from the one in Nordic Countries. In Russia before the permit for construction activities for a specific location has to be acquired before the preparation for production stage. It means that the design has to be final before the permit for construction is acquired. In other words, after the building permit has been acquired, the design officially cannot be changed. Referring to the figure 11, it means that the after the design stage box, the design has to be confirmed.

According to Pennanen 2011 the target costing should be done before the design, thus providing guidance for design options. In the case with NCC, the planning stages that come before the design are plot acquisition, town planning, and management of utilities. Now, the cost estimation is useful during the plot acquisition and town planning phases, which are the part of the project planning phase. Although when the technical task for design is being created, it is useful to follow up on the target cost of the project that has been estimated during the planning phase. The reason for emphasizing this follow-up is that the time interval between land acquisition and technical task for design might be as long as couple of years. So in this case we are speaking about the cost estimation as the benchmarking tool that helps in design steering process. In practice it means that when the project cost has been estimated in the beginning, managers have to have more or less clear picture of what kind of project scope is feasible for acquired plot. During the design stage though, the design options for the project are benchmarked towards the project scope that has been decided during the planning stage of the construction project. This will result in more suitable design options for project.

Cost estimation is developed through "learning by doing" process, which means that historical cost estimations will be taken into account while making new cost estimation, which results in more precise figures with every new project. In order to develop this process, the cost estimation during the design stage is actually a vital benchmark where it outlines the difference between cost during the planning and the design phase. Regardless of how precisely the project cost is estimated in the planning phase of the construction project, there are always details that have not been taken into the account and occur during the design phase, so cost estimators are allowed for the deviation in the project cost calculations. Again, Pennanen (2011) is correct about the fact that the ignition for the design should come from targeted project cost planned in the early stage of the project, nevertheless target costing methodology should not end when the design stage begins. By implementing the cost estimation during the planning and design stage of the project, company ends up with more precise project cost before the production phase.

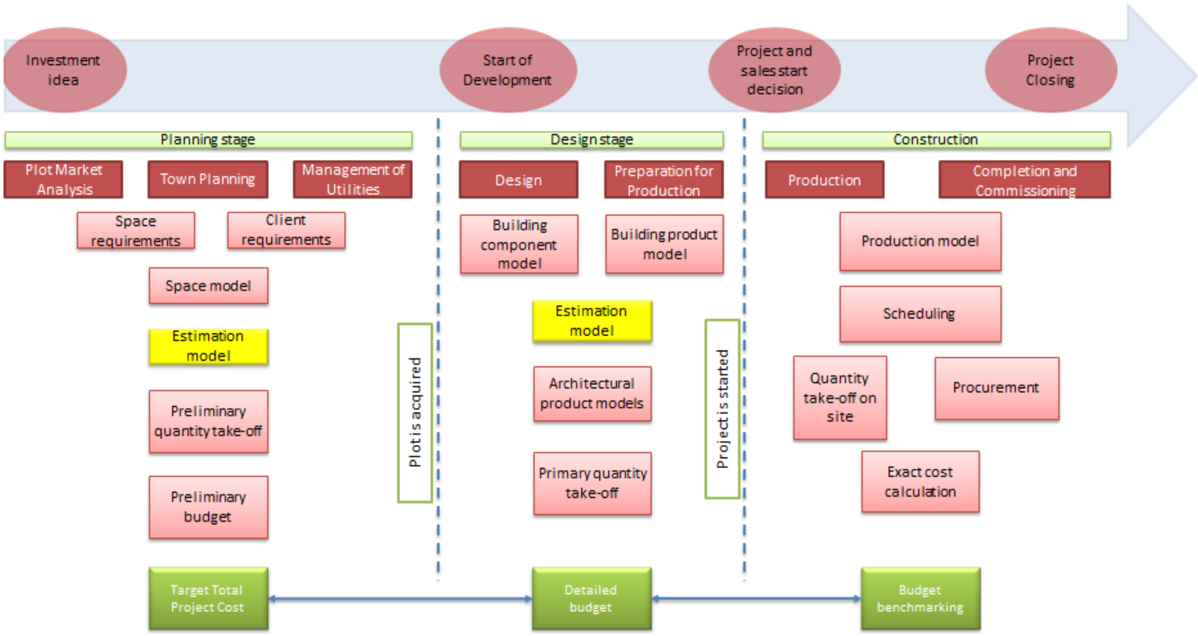
3.1.3 The Value of the Estimation Model in Design Management of NCC

In the previous section we have discussed the role of the cost estimation model in the design management process in NCC. This section will emphasize the value of using the consistent model in estimating construction costs in new production and the role of estimation model in design management process of NCC.

In the literature review the study has covered the target costing methodology which is the foundation of cost estimation technique used, for example, by Haahtela Group. Also the study has mentioned that in order for cost estimation calculation to bring the optimal value for the project, there has to be a certain consistent technique developed. For example the calculation has to be done in a certain matter for all the projects for preciseness to be developed with every project. Another point is that construction project is a complex process with multiple counterparties, therefore the calculation process usually involves handling data of the whole construction project nomenclature. On that account it is wise to use calculation software that handles data efficiently. MS Excel is an efficient tool for data handling because it allows creating empty calculation models and adjusting it depending on the project type. Based on that, the estimation model in NCC is a MS Excel based calculation model that contains default estimation of the certain construction project based on the location. Thereafter cost estimation engineers modify the calculation based on the estimated information linked to the project. Thus the use of cost estimation model results in efficiency increase and time-saving for managers and cost-estimation engineers.

Now that the research has identified the role of the estimation model, with the help of design management process from NCC and quantity take-off graph from Firat (2010) the research has designed the graph where the toll gates from housing process and quantity take-off process are combined. The motivation for combination these two graphs is that quantity take-off is the key procedure in construction project that is done after the project cost is estimated. Moreover the estimated project cost directly correlates with the quantity take-off amount. For example the higher the price of the project the more positions are included in quantity take-off. In this example we assume that we compare typical residential houses in the same location. While NCC Housing Process Model shows the path for residential unit production, the quantity take-off figure by Firat (2010) shows general process of the construction project quantity take-off from the customer to the project implementation. In the graph below the study has optimized Firat's model for NCC based on NCC Housing Model and identified where the construction cost estimation model should be used.

Figure 12 Cost Estimation Model in the Design Management Process



Source: (NCC Housing, Russia)

The function of estimation model in design management process is presented in the figure 12. The planning stage represents toll gates 0 and 1 where the estimation model is necessary for targeting the project budget. The design stage represents toll gate 2 when the project starts to develop, therefore the technical task for design is issued. Overall, the goal of the cost estimation is to give us preliminary reliable cost figures, so in a sense all we care about is target project cost and budgets (Boytsov, et al., 2013). Nevertheless, the correct budget cannot be estimated without the project background. In other words, preliminary budget figures have to be backed-up by the information on historical data. That is where the estimation model we have identified earlier comes into place. The space model is inputted into the estimation model which provides quantity of materials needed for the project and its price. When the quantity is checked by the cost estimation engineers the project receives the preliminary budget which assists in identifying the project scope. After the scope is decided, the development phase starts where the design stage initiates. Later on in the case study section, this study will define how important the correct historical data is for the cost estimation to be valid.

When the preliminary budget is being set-up during the planning stage, it gives guidance for design technical task of the construction project. Now according to target costing methodology, the design is the outcome from the project cost during the planning stage of the project, but also we know that during the design stage minor changes always come to the project scope, thus it is useful to take them into the account into the cost estimation model. This will allow understanding the difference between the estimated project cost and detailed project budget after the design (Boytsov, et al., 2013).

3.2 Construction Cost Estimation Model Design

In the previous section the study has identified the role of cost estimation model in design management process in NCC. Also, in the previous section the study outlined the value of using the consistent cost estimation model not only during the planning stage of the construction project but also benchmarking during the project's design stage. The next section will construct the cost estimation model which will be used in the case study.

3.2.1 Basics of Cost Estimation Model

The model is based on the target costing methodology and implies the project cost based on the demands for space. Therefore before jumping into the mathematical application of the model, we have to define the term demand for space. Demand for space implies external factors that influence the specifications of a certain space depending on its targeted usage. This definition is based upon the basis of space requirements defined by Haahtela and Kerkkänen who stated that space requirements are influenced by construction regulations, laws, and acts. Also, demands for space change depending on the construction type and its usage (Haahtela & Kerkkänen, 1991, p. 13). In our application with NCC it will be reflected in case if we want to create certain space for residence we should automatically take into the account the amount of common areas and its features. For example in the residential space there is a demand for heating to be +22 degrees Celsius which means that there has to be certain equipment and space for it to provide this kind of temperature year around. Now, the key factor here is to identify which kind of demands to consider when doing estimation for a certain construction project. The demands for space depend on the location, building type, and its usage (Kerkkänen, 2013). This means that if we want to estimate cost for residential six stories building in Helsinki Metropolitan Area (HMA), the demands for space are going to differ if we estimate the same building in St. Petersburg.

We have defined what we mean by demand for space in a construction. Besides demands for space, cost estimation model is based on the criteria for cost of the space or premises. The premise costs are based on the targeted usage of the construction project. This part of the cost estimation model can be directly influenced by cost estimation engineers. For example if demands for space allow construction of six and seven story buildings on the same area, decision makers decide which option would be more suitable for the location of the construction project. The price, of course, will have direct correlation with the amount of stories built. For better understanding the two aspects of the cost estimation model are presented in the table 5.

Table 5 Space-based Demands and Premise Costs

DEMANDS	**FACILITY COST BASIS**
DIMENSIONING, SHAPE AND ADAPTATION	FLOOR
Purpose of usage	*Net room area m2*
Basis of dimensioning	*Width*
Height	*Span*
Adaptiation	*Load*
Shape	*Floor finishing*
	Special structure
INDOOR AIR	
Minimum temperature, winter C	WALLS
Maximum temperature, summer C	*Wall with window m2*
Draughtiness	*Windows m2*
Ventilation supply sm2	*Interior door pcs*
Relative humidity	*Special interior door pcs*
Thermal stress	*Special entrance door pcs*
	Partition wall m2
LIGHTNING	*Special partition wall m2*
Artificial light Illuminance lx	*Finish of the wall m2*
Natural light through window per m2	
	CELING
FIRE SAFETY	*Room height m2*
Smoke removal hatches	*Floor height m2*
Fire safety exit	*Garret window m2*
	Ceiling finishing m2
EXPERIENCE	
Parking place per sqaure meter	STRUCTURE
	Inner partition walls m2
MAINTENANCE AND DURABILITY	*Inner doors pcs*
	Furniture, equipment pcs
LOCATION, CONNECTION, OTHER FACILITIES	Stairs pcs
	Heating %
COURTYARD LAYOUT	
	HVAC
EQUIPMENT AND SYSTEMS	*Furniture and fittings*
	Tap pcs
	Sewer pcs
	Supply air + exhaust m2
	Exhaust air
	Heat recovery
	Cooling
	Air distrubution
	HVAC range m2
	ELECTRICITY

	Lightning W/m2
	Socket outlet pcs
	Telephone socket pcs
	OTHER FACILITIES
	Lift shaft m2
	Common areas m2
	Engineering and utility services room m2
	OUTDOOR
	Yard area m2
	Paving
	Surfacing
	Bush plantings ratio
	Lawn ratio
	Drainage ratio

Source: (Haahtela & Kerkkänen, 1991)

The table 5 presents segmentation of elements included into the cost estimation model into demand for premises and facility cost basis. The main difference between these two columns is that demand for space does not assume cost for each position whereas cost for premises represents the amount of equipment and materials that are included into the project. In that sense, the demands for premises influence the cost base part and identify quantity of materials and its features.

One of the research tasks of the study is to find out whether the existing NCC cost estimation model can be estimated in St. Petersburg, Russia. This question will be answered profoundly in the next chapter with the help of the case study. This section will outline the technical parameters that have to be included into the model and the price adjustment methodology.

3.2.2 Determining Technical Parameters for Estimation Model

This section will concentrate on describing how the technical parameters are included when estimating specific project. This section will aim to answer the second research question and the sub question of what technical parameters should be included in the estimation model. The identification of valid parameters will be based on the framework in current estimation model used in NCC.

Before going into the technical parameters, the study will elaborate on how parameters framework. In the previous section we spoke about demand for space and basis for facility costs. Based on demands and cost basis, there is a default building type which is created for a specific location. The default building or premise type means a base model for the certain building depending on its usage and location which includes unique technical parameters (Kerkkänen, 2013). As an example if we decide to construction residential apartment house in the Helsinki city center, it will contain its unique base model which has calculated necessary parameters based on demands before facility cost basis is being modified. In practice it means that estimation model discerns where the building is being produced and what would be the estimated cost based on the demands for the space in the specific area. So, if we want to answer the research question if the model can be implemented in St. Petersburg, Russia, we have to keep in mind that it requires creating the default building for that area.

Based on the model used in NCC, the default model for the building includes parameters presented in the list below.

- type of building
- default floor size
- exterior wall thickness
- interior wall thickness
- facade coefficient
- frame depth
- stair input m2
- elevator input m2
- max number of floors
- foundation coefficient
- foundation depth
- base floor supported by ground
- base floor supported against the ground
- ventilated base floor
- ventilated base floor, semi heated
- arcade
- load-bearing separating walls
- stiffened separating walls
- pillar in basement
- default pillars
- pillar in hall
- floor slabs
- floor beams basement
- metal part in windows
- windows placing
- floor beams, default
- stairs in the staircase
- outdoor levels 1 BALCONIES
- outdoor levels 2 Loft
- plot limit construction accounted for
- outdoor levels 3 ROOF TERRACE
- heated basement, exterior walls
- floor slab thickness
- yard's proportion to the building
- storm water drainage other yard
- share of the asphalt in the yard
- share of tiles in the yard
- shrub plantings

- trees planting
- wire fence around the yard
- yard fence
- car shelters
- other shelters, part of the yard
- heating socket
- flagpole
- other yard equipment
- not demanding canopy
- demanding canopy
- the need for parking
- parking lot
- balcony m2
- open gallery m2
- double facade
- gravel yard
- floor drain / construction site
- management / water faucet
- indoor ventilation
- electricity mounting
- outdoor lighting
- the effectiveness of zoning
- semi-heated basement
- unheated basement
- heated rooms, exterior walls
- semi- heated space
- unheated space
- heated hall
- semi-heated hall
- unheated hall
- small radiators' proportion
- convectors proportion
- sewage and drainage
- lighting control
- presence sensor device
- cold storage
- freezer
- glass wall
- double facade
- skylights
- heat insulated walls
- architectural design
- structural engineering
- HVAC design
- electrical design
- real estate tax

- curbstone per asphalt coefficient m2
- elevator price coefficient
- cast iron share in sewage
- taxation value EUR/brm2
- technology default
- special structure 1 m2/br2
- sprinkler
- water charge
- electric charge

The list above represents the parameters according to which the construction cost estimation model in NCC identifies default building or facility. The parameters' set depends on the building type and its location. For example office building will have different sanitary equipment included in the default facility rather than residential building because of the number of users per square meter.

The construction project is never a default building only. It includes more parameters depending on the apartment plan which determines the project scope. So later in the case study chapter besides getting the data to determine what kind of the default facility the project will carry, it will be necessary to get the data for parameters of separate spaces in the whole building.

3.2.3 Price Adjustment Method in Estimation Model

Previous section described the technical parameters that form the physical frame of the project. This section will cover the method of the price adjustment in the estimation model in NCC.

The second research question addresses the issue of cost estimation methodology for various projects. Even if the model has technical aspects of the project in place, the concern shifts to the price level of the estimation. In order to achieve valid estimated price we have to have the valid unit price for each parameter (Eskola & Kerkkänen, 2013).

The estimation model itself contains the database of the all the possible parameters that are included in the building construction in Nordic Europe. They are sorted according to the Finnish system registry Talo 80. Each parameter is priced according to its market price in 2005 and therefore indexed to the correct amount nowadays. The cost estimation model approaches parameters' pricing by dividing them into two main categories. Each category has also subcategories for setting up the price more precisely. The table 6 shows the index categories used in the estimation model.

Table 6 Index Categorization in Estimation Model

Labor	Material
Design	Earthwork
Sheetmetal work	Filling
Masonry, tiling	Concrete reinforcement
Carpenter work	Concrete
Painting work	Precast concrete
Mechanical	Metal structures
Other skilled labor	Timber
Other works	Timber structures
Work superintendence	Bricks, tiles
	Machinery
	HVAC, electrical equipment
	Equipment
	Other materials

Source: (Kerkkänen, 2013)

In the table above the project cost is divided into two major categories and multiple subcategories. This is made for convenience in adjusting the price of the project by categories. Each price category has the base index of 2005 in Finland, therefore instead of comparing each parameter, and those are around 3000 in the database, cost estimation engineers can adjust subcategory under the “labor” or “material” groups via indexing the cost group of the model. Thus, price of each parameter in the nomenclature represents the relationship of subcategories relevant for each parameter. For example the concrete slab will have certain percentage of “precast concrete” and “other skilled labor” categories depending on the slab type. After the subcategories are adjusted, the model calculated the aggregate index of the project. For example while estimating the construction project in Helsinki Metropolitan Area, the labor category most likely will have higher index than in St Petersburg. So by adjusting subcategory index, we do not have to go through every position accounted for worker and adjust the unit price. Of course if cost estimation engineer notices noticeable difference in price of one labor unit, it can be adjusted.

Using the indexing technique in the estimation model, other projects in different locations can be estimated using the same consistent estimation model. Of course it requires set up and testing if the adjusted index is valid for certain location before the model can be used. It is advised to test the model on the construction project that has been already commenced to the production stage because the total project budget has been calculated and is sufficient for model estimation benchmarking (Eskola & Kerkkänen, 2013).

3.2.4 Mathematical Framework for the Estimation Model

From the mathematical perspective we can use the formula provided by Chou (2011) to show the calculation of the construction cost estimation:

$$TPC = \sum_{j=1}^{n} ItemCost_j$$

Where:

- *TPC* is Total Project Cost
- $ItemCost_j$ is the cost of the *j*th work item
- *n* is the number of work items in the project

Source: (Chou 2011)

Applying this formula for the estimation model in NCC, we can form the following equation:

$$TPC = \sum_{j=1}^{n} Item_j \times Quantity_j \times UnitPrice_j$$

Where the total project cost is the sum of the quantity of parameters ($Item_j$) and their price ($UnitPrice_j$). It can be noticed that challenge is not to solve for the mathematical equation, but rather to identify the suitable parameters' quantity and its price. The research path for researching for the suitable quantity and price of parameters will be discussed in the following chapter.

4 Construction Cost Estimation Model Application in St. Petersburg, Russia: Case Study.

The previous chapter concentrated on the model description used in NCC. This chapter will research if the existing estimation model can be adjusted and used in St. Petersburg, Russia. This chapter will begin with data collection for the case study, then it will shift to the model estimation based on the existing technique used in the company, then the model will be back tested with the help of the budget calculation of the project used in the case study, and finally this chapter will be concluded by results' analysis. The aim of this chapter is to fully answer the second research question of the study. After the model estimation, this section is going to address the third research question regarding model's reliability and usability in St. Petersburg, Russia.

In the literature review of the study it was mentioned that the main purpose of the cost estimation is to identify the project scope in the early planning stage of the construction project. Early stage is defined as the stage at which there is no project documentation, nor any kind of design. This study, therefore, will simulate the real life situation by estimating the project scope as if the budget for it has not been calculated. Although for the testing and benchmarking purposes, the study will compare the estimation results with the actual budget and project documentation. The purpose for benchmarking is to test whether the existing estimation model is suitable for implementation and usage in St. Petersburg and which parts require attention (if any) to produce reliable estimation results for future projects.

4.1 Project background

Before the data collection for construction cost model estimation, it will be useful to briefly mention about the construction project that is used in the study. The project itself is a block of medium-tall houses which is located in of St. Petersburg, Russia.

Figure 13 Area Plan of the Case Study Project

Source: (NCC Housing, Russia)

This study will take into the account only the first construction stage of the project which includes two buildings six stories each which are marked with blue on the map (1.1 and 1.2). The reasons for using only the first construction stage in the case study are:

1. The first stage has a detailed project budget.
2. The construction site running costs are calculated for two buildings, therefore it is easier to benchmark against estimation model results against the whole construction stage rather than against one building.

The land area included in the case study is about 3500 - 4000m^2 and it includes proportional part of the yard area in its cost estimation.

4.2 Data Collection and Arrangement

The data is collected based on the construction cost estimation model framework discussed in the previous chapter. First, the cost estimation model will determine the default premise based on the construction features gathered, and then the model will input room plan of project used as a case study. The data for the default premise is collected from the project plan and documentation including architectural drawings. The data for the room plan is also collected with the help of project documentation and the interviews with responsible project engineers.

4.2.1 Identifying the Default Premises of the Project

In the previous chapter we have mentioned that the default premise means the base building model depending on its usage and surroundings. This section will define base building for NCC in St. Petersburg area based on the default premise framework presented in the previous chapter. The table 7 below presents the default premise framework.

Table 7 Default Residential Premise Framework for Cost Estimation Model

Parameter	Premise 1	Premise 2
The default floor size m2	500	600
exterior wall thickness cm	0,26	0,3
interior wall thickness cm	0,18	0,18
facade coefficient	1,15	1,05
frame depth m	12	17
stair input m2	300	600
elevator input m2	300	600
max number of floors	20	20
foundation coefficient	3	4
foundation depth m	10	1,7
base floor supported by ground	*26000001*	*26000006*
base floor supported against the ground	*26000005*	*26000005*
ventilated base floor	*23100001*	*23100001*
ventilated base floor, semi heated	*23100002*	*23100002*
arcade	*55013503*	*55013503*
load-bearing separating walls	*32300002*	*32300002*
stiffened separating walls	*32300004*	*32300004*
pillar in basement	*32500001*	*32500001*
default Pillars	*32500001*	*32500001*
pillar in hall	*32500002*	*32500002*
floor Slabs 1	*33100002*	*33100007*
floor Slabs 2	*33100002*	*33100002*
floor beams basement	*33400001*	*33400001*
metal frame in windows ratio	0,1	0
windows placing (North South)	50	50
floor beams, default	*33400001*	*33400001*
stairs 1 staircase	*34200000*	*34200000*
stairs 2	*34503501*	*34503501*
Stairs 3	*34606503*	*34606503*
outdoor levels 1 BALCONIES	*36000001*	*36000002*
outdoor Levels 2 Loft	*36000014*	*36000014*
plot limit construction ratio	0	0
outdoor Levels 3 ROOF TERRACE	*36000002*	*36000002*
heated basement, exterior walls	*35100008*	*35100007*
floor slab thickness cm	0,3	0,3
yard's proportion to the building ratio	0,5	0,5
water drainage yard area m2	300	300
share of the asphalt in the yard ratio	0,2	0,2
share of tiles in the yard ratio	0,2	0,2
shrub plantings ratio	0,1	0,1
trees planting ratio	0,01	0,01
wire fence around the yard m	0	0
yard fence ratio	0,02	0,02
car shelters m2	30	0
other shelters, part of the yard ratio	0,005	0,003
heating socket pcs	100	0
flagpole pcs	1	0
other yard equipment pcs	3,3	3,3
not demanding canopy ratio	0	0
demanding canopy ratio	0	0
the need for parking pcs/m2	60	80
parking lot factor	3	3
balcony m2	0,15	0,07
open gallery m2	0	0
double façade m2	0	0
gravel yard ratio	0,2	0,04
floor drain / construction site pcs	0	0

management / water faucet pcs	14	14
indoor ventilation factor	1	1
electricity mounting factor	0	0
outdoor lighting ratio	0,005	0,005
the effectiveness of zoning ratio	0,8	0,8
semi-heated basement	*35100005*	*35100005*
unheated basement	*35100002*	*35100002*
heated rooms, exterior walls 1	*35805115*	*35300046*
heated rooms, exterior walls 2	*35300030*	*35300030*
heated rooms, exterior walls 3	*35300040*	*35300040*
semi- heated space	*35260002*	*35260002*
unheated space	*35220000*	*35220000*
heated hall	*35270002*	*35270002*
semi-heated hall	*35260011*	*35260011*
non-heated hall	*35200001*	*35200001*
arcade ratio	NA	NA
small radiators' proportion pcs	25	0
convectors proportion pcs	NA	NA
sewage and drainage pcs/m2	3,4	3,4
lighting control ratio	NA	NA
presence sensor device	NA	NA
cold storage	*35270331*	*35270331*
freezer	*35270341*	*35270341*
heated space	*41000002*	*41000005*
semi-heated space	*41500020*	*41500020*
non-heated space	*41500030*	*41500030*
heated hall	*41500040*	*41500040*
semi-heated hall	*41500050*	*41500050*
non-heated hall	*41500060*	*41500060*
glass wall	*41500010*	*41500010*
double facade	*35900010*	*35900010*
skylights	*42003310*	*42003310*
heated space	*37100006*	*37100006*
heated space 2 ventilation	*37400000*	*37400000*
heated space 3 trafficked	*37600000*	*37600000*
semi-heated space	*37100002*	*37100002*
non-heated space	*37400021*	*37400021*
heated hall	*37200002*	*37200002*
semi-heated hall	*37200003*	*37200003*
non-heated hall	*37200004*	*37200004*
cold storage	*NA*	*NA*
freezer	*NA*	*NA*
heat insulated walls	*NA*	*NA*
architectural design ratio	70	70
structural engineering ratio	70	70
HVAC design ratio	80	80
electrical design ratio	80	80
real estate tax ratio	0,22	NA
pre-handover self-inspection ratio	0,15	NA
curbstone per asphalt coefficient m2	0,3	0,3
elevator price coefficient	1	1
cast iron lid share in sewage pcs	10	12
taxation value EUR/brm2	468,07	NA

Source: (Kerkkänen, 2013)

The table 7 contains the data to for creating a default premise model used in cost estimation. The column 1 represents the given data of the default premise in Finland (residential apartment house). The second column represents the data for the default premise in St. Petersburg, Russia. Each parameter is represented either in ratio to the total floor area of the project, in coefficient, in metric scale, or in parameter position number in cost nomenclature. The cost nomenclature is divided into groups according to the Talo 80 system.

4.2.2 Identifying Space Plan Parameters

The building of the room plan is the core of the technical parameters in the estimation model. The rooms' amount and size determines the amount of materials used for the project. The default premise building model only determines the framework according to which the project cost will be calculated. In order to do the model estimation of any project it is important to decide what would be the use of the building and what is approximate project scope. For example, it is going to be three story office building or 20 story residential building. During the project planning phase managers might not necessarily be certain about the project scope, so in this case it is possible to do multiple estimation models to evaluate the cost of each opportunity and to compare which one suits for the given location. Nevertheless, in this study we assume that we are certain about the project scope, therefore the room plan in this research is quite precise.

Table 8 Room Plan for Case Study

Space input	Total area m2	rooms' amount	room area	Total flat area
1 st flat				1 034
Bathroom RUS	56	12	4,7	
Hallway RUS	151	12	12,6	
Kitchen RUS	210	12	17,5	
Room RUS	217	12	18,1	
Room RUS	197	12	16,4	
Room RUS	145	12	12,1	
Sauna stove room RUS	36	12	3	
Toilet RUS	22	12	1,8	
2nd flat				800
Bathroom RUS	46	12	3,81	
Hallway RUS	146	12	12,16	
Kitchen RUS	268	12	22,37	
Room RUS	130	12	10,86	
Room RUS	170	12	14,14	
Sauna stove room RUS	27	12	2,25	
Toilet RUS	13	12	1,07	
3d flat				535
Bathroom RUS	59	12	4,92	
Hallway RUS	81	12	6,76	
Kitchen RUS	225	12	18,78	
Room RUS	170	12	14,13	
4th flat				816
Bathroom RUS	54	12	4,47	
Hallway RUS	105	12	8,73	
Kitchen RUS	273	12	22,77	
Room RUS	192	12	15,98	
Room RUS	176	12	14,64	
Toilet RUS	16	12	1,37	
5th flat				749
Bathroom RUS	42	12	3,47	
Hallway RUS	83	12	6,88	
Kitchen RUS	208	12	17,36	
Room RUS	134	12	11,13	
Room RUS	133	12	11,21	
Room RUS	133	12	11,06	
Toilet RUS	17	12	1,4	
6th flat				653
Bathroom RUS	39	12	3,29	
Hallway RUS	136	12	11,32	
Kitchen RUS	152	12	12,67	
Room RUS	168	12	13,97	
Room RUS	137	12	11,45	
Toilet RUS	21	12	1,72	
7th flat				806
Bathroom RUS	71	12	5,95	
Hallway RUS	99	12	8,27	
Kitchen RUS	226	12	18,8	
Room RUS	213	12	17,79	
Room RUS	137	12	11,42	
Sauna stove room RUS	30	12	2,51	
Toilet RUS	29	12	2,41	
8th flat				456
Bathroom RUS	44	12	3,7	
Hallway RUS	76	12	6,35	
Kitchen RUS	180	12	15,01	
Room RUS	156	12	12,97	
Common areas				426
Corridor in the apartment house, RUS	421	12	35,1	
Wind box RUS	5	2	2,3	
Basement				924
Corridor in the basement	226	2	113,06	
Hallway in storage room	232	20	11,62	
Storage Room RUS	435	106	4,1	
Cleaning closet RUS	10	2	4,9	
Storage Room RUS	21	1	20,56	

Source: (Petrov & Soloshenko, 2013)

The table 8 displays the room plan for the case study. The total gross area is estimated to be 7200 m^2. This figure excludes staircase and technical rooms because the model will estimate them based on the default premise building model. The reason that staircase and technical rooms are estimated is that during the planning stage managers rarely can tell the exact scope of those spaces. While planning the new residential project, managers usually act as designers, and therefore think about the project as a whole. In this sense, the technical room is the space that can be easily underestimated or even forgotten while thinking about the actual space for users (Kerkkänen, 2013).

In the room plan we have identified the total project scope of the underlined construction project. The next step is to identify the profile of each space. The default premise model sets up estimated parameters for the whole project, although there are certain adjustments needed to be made to each space unit of the project in order to estimate the most correct project cost. This is the most time consuming job of the cost estimation, especially if there is no historical estimations done for the suitable location and default premise model.

Each space model framework has parameters that have to be identified in order to construct the infrastructure of the construction project. The table 9 below displays the space model.

Table 9 Space Parameters for the Case Study

	Bathroom	Hallway	Kitchen	Bedroom	Sauna
GEOMETRY					
Free room height m	2,8	2,8	2,8	2,8	2,6
Total room height m	2,8	2,8	2,8	2,8	2,8
Span m	9	9	9	9	9
USE					
Purpose	residential	residential	residential	residential	residential
Minimum temperature, winter oC	20	18	18	20	18
Maximum temperature, summer oC	27	27	27	27	27
Adjustability in each room	no	no	no	no	no
Mechanical supply air, minimum l/ms2	0	0	0	0	0
Air speed, maximum, winter m/s	0,2	0,2	0,2	0,2	0,2
Mechanical exhaust air, minimum l/sm2	0,4	0,4	0,4	0,4	0,4
Exhaust air rating	1	1	1	1	1
Illuminance lx	150	150	150	150	400
Lighting properties	no fixtures	no fixtures	no fixtures	no fixtures	common area fixtures
Load from electric appliances m2	120	120	120	120	140
Design heat load for equipment m2	10	10	10	10	10
Continuous heat load of equipment m2	1	1	1	1	1
Smoke removal hatches %	0	0	0	0	0
Skylight %	0	0	0	0	0
Natural light through window m2	0	0	2,6	2,7	0
Exterior door pcs	0	1	0	0	0
Special door, to the outside m2	0	0	0	0	0
Separate sewerage	no	no	no	no	no
Floor load, minimum kN/m2	1,5	1,5	1,5	1,5	2,5
Floor load, reserve %	0	0	0	0	0
SPACE STRUCTURES					
Door to space pcs	0	1	0	0	1
Load-bearing partitions	PRECAST	PRECAST	PRECAST	PRECAST	PRECAST
Non-load bearing partitions	Gypsum board	Gypsum board	Gypsum board	Gypsum board	Gypsum board
Special partition					
Railing or no partition					
Internal partitions					
Internal special partitions	Metal flue element				
Internal railing					
INTERNAL SURFACE STRUCTURES					
Wall painting		ground painting	ground painting	ground painting	
Wall facing	Water proofing				wall covering
Ceiling painting					
Ceiling surface		Sprayed filler	Paint	Sprayed filler	softwood
Subfloor structure	slope screed	screed	screed	screed	slope screed
Floor covering	water proofing				tiles
Skirting					
FURNITURE, FITTINGS, EQUIPMENT					
Equipment					Stove, benches
PLUMBING WORK					
Sanitary fixture	plumbing		plumbing		floor trap
Sanitary fixture	toilet seat				

Heating	space radiator	radiator	radiator	radiator	radiator
Convenience floor heating, electrical	no	no	no	no	no
ELECTRIC SYSTEMS					
Electric fitting, plugboxes	2	2	3	3	
Electric fitting, plugboxes		intercom device	RJ connector	RJ connector	
Electric fitting, plugboxes			Antenna points	Antenna points	

	Toilet	**Corridor**	**Windbox**	**Basement corridor**	**Storage room hallway**
GEOMETRY					
Free room height m	2,8	2,5	2,5	2,4	2,4
Total room height m	2,8	2,8	2,9	2,8	2,8
Span m	9	9	9	9	9
USE					
Purpose	residential	shared	shared	shared	shared
Minimum temperature, winter oC	18	18	20	18	18
Maximum temperature, summer oC	27	27	27	27	27
Adjustability in each room	no	no	no	no	no
Mechanical supply air, minimum l/ms2	0	0	0	0	0
Air speed, maximum, winter m/s	0,2	0,3	>0,3	0,3	0,2
Mechanical exhaust air, minimum l/sm2	0,4	0,4	0	0,4	0,4
Exhaust air rating	1	1	1	1	1
Illuminance lx	150	200	200	200	200
Lighting properties	no fixtures	common area fixtures	common area fixtures	common area fixtures	common area fixtures
Load from electric appliances m2	120	20	10	20	30
Design heat load for equipment m2	10	10	2	10	10
Continuous heat load of equipment m2	1	1	0	1	1
Smoke removal hatches %	0	0	0	0	0
Skylight %	0	0	0	0	0
Natural light through window m2	0,3	7	0	22,6	0
Exterior door pcs	0	0	1	1	0
Special door, to the outside m2	0	0	0	0	0
Separate sewerage	no	no	no	no	no
Floor load, minimum kN/m2	1,5	1,5	2,5	1,5	1,5
Floor load, reserve %	0	0	60	0	0
SPACE STRUCTURES					
Door to space pcs	0	1	2	1	1
Load-bearing partitions	PRECAST	PRECAST	PRECAST	PRECAST	PRECAST
Non-load bearing partitions	Gypsum board	brick	brick	brick	brick
Special partition					
Railing or no partition					
Internal partitions					
Internal special partitions					
Internal railing					
INTERNAL SURFACE STRUCTURES					
Wall painting		painting	painting	painting	painting
Wall facing	Water proofing				
Ceiling painting					
Ceiling surface		Suspended ceiling	Suspended ceiling	Sprayed filler	Sprayed filler

Subfloor structure	screed	screed	screed	polyethylene membrane	polyethylene membrane
Floor covering		tiled	tiled	acrylic concrete	acrylic concrete
Skirting		tile skirting	tile skirting		
FURNITURE, FITTINGS, EQUIPMENT					
Equipment			mailbox		
PLUMBING WORK					
Sanitary fixture	plumbing				
Sanitary fixture	toilet seat space				
Heating	radiator	radiator	radiator	radiator	radiator
Convenience floor heating, electrical	no	no	no	no	no
ELECTRIC SYSTEMS					
Electric fitting, plugboxes	2	5	0	20	2
Electric fitting, plugboxes					
Electric fitting, plugboxes					

	Storage room	Cleaning closet	Staircase	Technical room
GEOMETRY				
Free room height m	2,4	2,4	2,5	2,5
Total room height m	2,8	2,8	2,8	2,8
Span m	9	9	9	9
USE				
Purpose	shared	shared	shared	shared
Minimum temperature, winter oC	20	20	16	20
Maximum temperature, summer oC	27	27	27	27
Adjustability in each room	no	no	no	yes
Mechanical supply air, minimum l/ms2	0	0	0	0
Air speed, maximum, winter m/s	0,2	0,25	0,25	0,25
Mechanical exhaust air, minimum l/sm2	0,4	2	0,4	0,5
Exhaust air rating	1	1	1	1
Illuminance lx	200	200	150	400
Lighting properties	common area fixtures	common area fixtures	common area fixtures	common area fixtures
Load from electric appliances m2	30	50	30	30
Design heat load for equipment m2	10	10	10	10
Continuous heat load of equipment m2	1	1	5	5
Smoke removal hatches %	0	0	0	0
Skylight %	0	0	0	0
Natural light through window m2	0,6	0	7,7	3,9
Exterior door pcs	0	0	1	0
Special door, to the outside m2	0	0	0	0
Separate sewerage	no	no	no	no
Floor load, minimum kN/m2	1,5	1,5	2,5	5
Floor load, reserve %	0	0	0	0
SPACE STRUCTURES				
Door to space pcs	1	1	1	1
Load-bearing partitions	PRECAST	PRECAST	PRECAST	PRECAST
Non-load bearing partitions	brick	brick	brick	brick
Special partition				
Railing or no partition				
Internal partitions				
Internal special partitions				
Internal railing			Spoke railing	
INTERNAL SURFACE STRUCTURES				
Wall painting	painting	painting	painting	
Wall facing				leveling

Ceiling painting				
Ceiling surface	Sprayed filler	Sprayed filler	Suspended ceiling	Sprayed filler
Subfloor structure	polyethylene membrane	polyethylene membrane	screed	floating floor
Floor covering	acrylic concrete	acrylic concrete	tiled	
Skirting			tile skirting	
FURNITURE, FITTINGS, EQUIPMENT				
Equipment		cleaning closet equipment		
PLUMBING WORK				
Sanitary fixture		lever mixer		
Sanitary fixture		basin		
Heating	radiator	radiator	radiator	radiator
Convenience floor heating, electrical	no	no	no	no
ELECTRIC SYSTEMS				
Electric fitting, plugboxes	2	2	2	2

Source: (Petrov & Soloshenko, 2013)

The table above is built according to the framework of the model design discussed in the third chapter (Table 5). Heading of each table represents individual space unit for which demands for space and cost parameters are collected for estimating the construction project.

4.2.3 Framework for Price Adjustment for St. Petersburg, Russia

The estimation model will give the total project cost amount depending on model's index in use. The index is determined according to the market where the project is calculated. For index calculation we are going to apply the framework we have discussed in the previous section (Table 6). The estimation model calculates the aggregate price index figure for the local market based on the cost framework where the base year is 2005. Aggregate NCC index for HMA and Tallinn in 2013 are 117.5 and 74,7 respectively. For the testing purposes we applied NCC index calculated for Tallinn and HMA to see which one will be the closest to the price level in St. Petersburg. The table 10 below presents the cost framework using price level of HMA and Tallinn.

Table 10 Price Indices in Estimation Model

Labor	Price Index HMA	Price Index Tallinn	Material	Price Index HMA	Price Index Tallinn
Design	108,2	54,6	Earthwork	114,6	47,7
Sheetmetal work	112,7	56,5	Filling	130,0	66,8
Masonry, tiling	120,6	57,0	Concrete reinforcement	113,3	90,0
Carpenter work	173,0	67,2	Concrete	118,5	93,6
Painting work	116,7	51,3	Precast concrete	124,8	79,6
Mechanical	122,0	60,0	Metal structures	98,9	82,4
Other skilled labor	124,1	57,0	Timber	92,7	82,4
Other works	86,1	39,0	Timber structures	105,1	93,6
Work superintendence	140,6	57,0	Bricks, tiles	106,1	103,0
Price Index Total	**125,5**	**57,6**	Machinery	110,2	104,0
			HVAC, electrical equipment	115,8	86,5
			Equipment	110,0	51,5
			Other materials	104,1	104,1
			Price Index Total	**114,1**	**84,2**

Source: (Kerkkänen, 2013)

The table above represents Tallinn price indices that will be used in the estimation model and HMA price indices for comparison. If we think about the index through the prism of the default premises, the estimation model adjusts the total price index according to the estimated project location. The reason for taking two price index markets is to see which index will be more accurate in the cost estimation of the underlined construction project.

4.3 Model Estimation

This section is going to estimate the construction project based on the data collected in the previous section of the study. The estimation procedure is actually not as time consuming as the data collection procedure of this study. As the study mentioned in the previous chapter, the calculation technique is relatively straightforward (formula by Chou 2011). Nevertheless the research for the valid data may be a challenge sometimes, especially if the estimation model is being tested for the location where there is little or no history of estimation construction project. The prior estimated projects play significant role in precise estimation results as the cost estimation model is based on case-based reasoning logic discussed in the literature review (An, et al., 2007).

4.3.1 Data Input

For the project cost estimation to be as accurate as possible, we have to define the default premise building model for St. Petersburg, Russia based on the second column of the table 7. The result of inputting the default values for premises in St. Petersburg, Russia is the technical framework of the building is more suitable for St. Petersburg. This allows faster and more accurate adjustment of the individual construction project rather than using default premise model of Finland.

After the default premise model is defined, the room plan for the project is inputted (table 8). The room plan defines the project scope. Depending on the default premise model, the room plan defines the amount features of parameters included in the estimation model.

The room plan defines the project scope as a whole, whereas through the technical framework for each space unit cost estimation engineer does the fine tuning for the estimated project.

After the technical parameters are inputted into the model, it immediately gives the price estimate by calculating the unit’s sum times price of each unit. The price of the project is divided into the price indices framework presented in tables 6 and 10. During the first estimation we are going to test which index fits St. Petersburg better HMA Index or Tallinn Index (Table 10).

4.3.2 Estimation Model Output

After inputting all the necessary information for the project into the construction cost estimation model we get the following results for using price indices of HMA and Tallinn.

Table 11 Scope Estimation for the Case Study

Total No. of buildings pcs	2
Total volume m3	26 865
Net floor area total m2	7 543
Area of structures m2	966
Gross area total m2	8 508
Saleable/leasable area m2	5 849
Area covered by building total m2	1 243
Perimeter of area covered by building l.m.	225

In the table above the project scope is calculated in the estimation model. The total number of buildings were identified manually, everything else was an input based on the default premise settings.

The next two tables show the total project cost using indexing of Tallinn and HMA. The reason for choosing to estimate with the help of indices from two different locations is to see which location index will provide the closest estimate to the actual project cost. The reason for using particularly Tallinn index is that it is geographically close to St. Petersburg and the construction cost estimation model in NCC has been tested for the market in Estonia. The price estimation results are outputted in Russian currency rubles, in future referred as RUB. The exchange rate used in the estimation is 44,00 RUB for 1,00 EUR.

Table 12 Price Estimation for the Case Study

Cost Category	Index HMA RUB	Index Tallinn RUB
EARTHWORK AND SUBGRADE	20 911 513	10 697 586
FOUNDATIONS AND EXTERNAL STRUCTURES	10 437 316	6 537 412
FRAMING AND ROOFING	85 796 728	56 399 878
SUPPLEMENTARY STRUCTURES	57 898 458	42 140 824
SURFACE STRUCTURES	31 957 037	19 676 279
FURNITURE, FITTINGS, EQUIPMENT	220 041	164 457
MECHANICAL WORKS	56 952 559	39 054 526
SITE RUNNING COSTS	26 059 847	19 560 367
SITE OVERHEAD COSTS	26 751 096	11 229 728
TECHNICAL PRICE	**316 984 595**	**205 461 058**

In the estimation results above the model presented the cost split into several categories. The technical price is the units' sum times the price of each unit.

This section has addressed the second research question by indicating that model can be estimated in Russian market using the existing methodology in Finland. First, the model breaks down the estimation results into cost categories according to the construction nomenclature logic of Talo 80. The reason for taking Finnish system for analysis of the construction project in Russia is that Russia does not have such unified reporting standard as Talo 80 in Finland (Boytsov, et al., 2013). Also Talo 80 system is easy to understand, as most of the cost accounting systems use similar logic. This results in more convenient benchmarking estimated and actual results of separate cost groups. Thus, usage of the existing nomenclature system results in shorter learning curve for the management as creating new cost accounting system and testing it.

4.4 Model Benchmarking

In the previous section we have inputted the data into the estimation model, and the model produced output based on the default premise applied for St. Petersburg, Russia. This section is going to benchmark the estimation model output against the actual project budget. The aim of this section is to begin addressing the third research question: can the estimation model results be reliable for St. Petersburg, Russia.

In order to understand the benchmarking process, there is a need to define requirements for estimation results to be satisfactory. The project scope output is defined satisfactory if the total difference is equals or less than 10% for the first test estimation. The project price output is considered satisfactory if more than 70% of the cost categories can be adjusted through index adjustment (no more than 50% difference).

4.4.1 Scope Benchmarking

The cost estimation model gave the scope output based on the default building model and the room plan provided for project estimation. In the table below we can see the estimated scope versus actual project scope.

Table 13 Project Scope Output Benchmarking

	Estimated	Actual	Difference %
Total No. of buildings pcs	2*	2	
Total volume m3	26 865	28673	6,7%
Net floor area total m2	7 543	7596	0,7%
Gross area total m2	8 508	8972	5,5%
Saleable/leasable area m2	5 849	6064	3,7%
Area covered by building total m2	1 243	1304	4,9%
Perimeter of area covered by building l.m.	225	220	-2,2%

*adjusted manually

The actual figures are taken from the project documentation of project. The difference in the scope between key parameters is not significant if we assume that the estimation has been done for the first time. It means that the data for the default premise model has been collected properly. The average difference accounts for 4%. One reason why the figures are not so significant is that the room model accounts for the most of the project scope in the estimation model. As we have taken the exact room plan from the project documentation, the estimation output is close to the actual result.

4.4.2 Project Price Benchmarking

Next, the study will compare the estimated project price against the actual calculated budget. The price is compared according to the framework in the table 12 in the previous section. The benchmarking is presented below.

Table 14 Project Cost Benchmarking against HMA Index

Cost Category	Index HMA RUB*	Actual Costs RUB*	Difference %
EARTHWORK AND SUBGRADE	20 911 513	16 572 776	20,7%
FOUNDATIONS AND EXTERNAL STRUCTURES	10 437 316	6 800 966	34,8%
FRAMING AND ROOFING	85 796 728	61 049 777	28,8%
SUPPLEMENTARY STRUCTURES	57 898 458	21 982 760	62,0%
SURFACE STRUCTURES	31 957 037	31 072 023	2,8%
FURNITURE, FITTINGS, EQUIPMENT	220 041	1 008 000	-358,1%
MECHANICAL WORKS	56 952 559	33 209 000	41,7%
SITE RUNNING COSTS	26 059 847	14 496 698	44,4%
SITE OVERHEAD COSTS	26 751 096	13 808 000	48,4%
TECHNICAL PRICE	**316 984 595**	**200 000 000**	36,9%

*static currency exchange rate

Table 15 Project Cost Benchmarking against Tallinn Index

Cost Category	Index Tallinn RUB*	Actual Costs RUB*	Difference %
EARTHWORK AND SUBGRADE	10 697 586	16 572 776	-54,9%
FOUNDATIONS AND EXTERNAL STRUCTURES	6 537 412	6 800 966	-4,0%
FRAMING AND ROOFING	56 399 878	61 049 777	-8,2%
SUPPLEMENTARY STRUCTURES	42 140 824	21 982 760	47,8%
SURFACE STRUCTURES	19 676 279	31 072 023	-57,9%
FURNITURE, FITTINGS, EQUIPMENT	164 457	1 008 000	-512,9%
MECHANICAL WORKS	39 054 526	33 209 000	15,0%
SITE RUNNING COSTS	19 560 367	14 496 698	25,9%
SITE OVERHEAD COSTS	11 229 728	13 808 000	-23,0%
TECHNICAL PRICE	**205 461 058**	**200 000 000**	2,7%

* static currency exchange rate

Two tables above represent the project calculated using two different locality indices, one of HMA and another of Tallinn. In the tables above we can see testing result of how accurate the estimation model estimated the project if the existing indices are used. For benchmarking purposes the study used current budget of the construction project. The budget was divided into the cost categories by comparing parameters in the estimation model with the parameters in the budget.

Two tables represent the same project from technical point of view, thus the price difference reflects the difference in the market price. The purpose for calculating the project with two different indices was to see which index gives more accurate estimation results. One of the study purposes is it to give recommendation for further cost estimation model adjustment for NCC in St. Petersburg.

4.5 Analysis of the Results

In the previous section the study has conducted quantitative research on estimating the construction cost estimation model for the existing project in St. Petersburg, Russia. This final section of this chapter will analyze the estimation model output and conclude by answering to the third research question of the study which addresses the reliability of the estimated model. This section will also show if the index adjustment is sufficient for achieving reliable results for further cost estimation project.

Looking at the role of the estimation model in the design management process discussed in third chapter, the cost estimation is used during the planning and the design stage. The reason for estimation model to be used also during the design stage is to benchmark the scope's change between the planning and the design stages.

Before going into the result analysis, the study will briefly comment on couple of things to be kept in mind during the results' analysis.

First, if we look at the cost category breakdown, the first category named Employer Costs is not included in the estimation. The reason for that is that in St. Petersburg this cost category is calculated separately using a different budget and there were no reliable figures that could have been used for benchmarking the estimated results.

Second, the default premise model of the building in St. Petersburg, Russia assumes that all apartments are estimated in shell and core, meaning that the finishing of the space is not included in the price. Looking at the table 9, it can be noticed that residential space has no equipment or furniture, nor painted walls. Compared to Finland, cost estimation engineers have to take into the account residential space with full finishing and basic equipment.

Third, the actual budget used for testing purposes in the study does not include budget for external utilities which, according to the rough estimate, accounts for 35 000 000 RUB for underlined project (Feshchenko, 2013). The reason for not using the utilities estimate for the testing purposes, because we cannot apply the same reserve for changes as for other cost categories. This part is left for further development of the estimation model.

4.5.1 Project Scope Benchmarking Analysis

The project scope has been estimated with the average difference in parameters of 4% which is low if assumed that the model has been estimated for the first time in the testing location. The reason why project scope estimated results was close to the actual result is that the inputted room plan is taken from the project documentation. As this project was taken for testing purposes, the exact room plan had to be used in order to study what will be the deviation of the estimation output of the scope compared to the actual calculations. The deviation in technical parameters is acceptable at this stage as it was expected to equal or less than 5% (Eskola & Kerkkänen, 2013).

The estimation model uses relationship of default premise model and requirements for space to calculate preliminary project scope. This is reflected in the total building volume, area covered by the building, and the perimeter of area covered by the building. The average difference of those parameters was 4,6%. The total volume figure showed the most of the deviation of 6,7%. This may be caused by difference in planning of external constructions of the project.

The difference in economic data parameters between estimated and actual results accounted for 5,5% in gross total area and 3,7% in saleable/leasable area. This means that we can trust estimation results while calculating future cash flows for possible future property owners.

Based on the project scope estimation the study can identify that the accuracy of the estimated results is sufficient for the model to be reliable for further implementation and usage and St. Petersburg, Russia. During the actual usage of the estimation model we have to remember that there are no actual project scope figures to be benchmark against, so naturally the deviation might increase between real-life estimations and actual project scope figures. But this may be also caused by a human interaction in project scope change.

4.5.2 Project Price Benchmarking Analysis

The goal of the price benchmarking is to understand which cost categories need adjustment for improving accuracy of further estimations. In the previous section the method of price adjustment was discussed. The goal of the price benchmarking is to show how different indices influence the price of the estimation.

The technical project price which is assumed to be 200 000 000 RUB. The technical price does not take into the account site profit and reserve for changes. Site profit and reserve for changes actualizes in the percentage from the technical price, thus depends on the management decision.

Based on the cost estimation output tables 14 and 15 we can see that the total difference in project cost is 36,9% for using HMA Index and 2,7% for using Tallinn Index. Looking individually at each cost category it can be noticed that the most out-of-range figure that needs attention is Furniture Fittings and Equipment which accounts for 358,1 and 512,9 percent difference for HMA and Tallinn indices respectively. Before starting the index adjustment, this cost category has to be studied by analyzing which technical parameters are included in the budget and the project cost estimate. It might be caused by misplacement of technical parameters in budget if we take the Talo 80 categorization of estimation model as the base for construction nomenclature for further use in St. Petersburg, Russia. Otherwise, the rest cost categories show the difference between estimation output and actual budget of no more than 62,0% and 57,9% of using HMA and Tallinn indices respectively.

As mentioned before, the goal of the price benchmarking analysis is to show how each index group influences the price on the same project and to analyze if the price adjustment is possible through group index adjustment. Index adjustment avoids the need adjust each individual 3000^{th} parameter’s price in the nomenclature. Instead it is possible to perform it via cost category framework presented in tables 14 and 15.

During the price benchmarking analysis the study can conclude that two out of eight cost categories in Tallinn Index and three out of eight in HMA Index showed excessive deviation. Excessive deviation means that the difference between estimated and actual results exceeds 50%. Different cost categories should be able to be adjusted via indexation of material and labor prices included in each parameter.

4.5.3 Index Generation for St. Petersburg Based on Benchmarking Results

After estimating project cost through using Tallinn and HMA indices, the study will attempt to adjust the pricing to the actual project cost using only indices of subcategories. First task is to compare sorted positions in the budget to the categories in the nomenclature and adjust the index depending on the price difference. For example if “Earthwork and Subgrade” pricing group contains parameter that is 20% cheaper, then we adjust the subcategories in the labor and material index categories accordingly. The result is modified index table presented in the table 16 and the estimation breakdown presented in the table 17.

Table 16 Adjusted Price Indices for St. Petesburg, Russia

Labor	Price Index Tallinn	Material	Price Index Tallinn
Design	54,6	Earthwork	43,4
Sheetmetal work	39,6	Filling	40,1
Masonry, tiling	45,6	Concrete reinforcement	108,0
Carpenter work	121,0	Concrete	84,2
Painting work	77,0	Precast concrete	71,6
Mechanical	60,0	Metal structures	57,7
Other skilled labor	88,4	Timber	74,2
Other works	54,8	Timber structures	93,6
Work superintendence	57,0	Bricks, tiles	72,1
Price Index Total	**66,9**	Machinery	145,6
		HVAC, electrical equipment	86,5
		Equipment	41,2
		Other materials	104,1
		Price Index Total	**78,9**

Table 17 Pricing for Case Study via Adjusted Indices

Cost Category	Index Adjusted Price*	Actual Costs RUB*	Difference %
EARTHWORK AND SUBGRADE	8 693 778	16 572 776	-90,6%
FOUNDATIONS AND EXTERNAL STRUCTURES	7 645 219	6 800 966	11,0%
FRAMING AND ROOFING	54 462 208	61 049 777	-12,1%
SUPPLEMENTARY STRUCTURES	38 749 766	21 982 760	43,3%
SURFACE STRUCTURES	20 437 582	31 072 023	-52,0%
FURNITURE, FITTINGS, EQUIPMENT	164 457	1 008 000	-512,9%
MECHANICAL WORKS	38 432 267	33 209 000	13,6%
SITE RUNNING COSTS	20 351 556	14 496 698	28,8%
SITE OVERHEAD COSTS	11 376 538	13 808 000	-21,4%
TECHNICAL PRICE	**200 313 371**	**200 000 000**	0,2%

* static currency exchange rate

Tables above indicate an attempt of price adjustment using only indices provided in the model. As described in the previous chapter, each technical parameter in the cost category represents the relationship of related materials and labor. The result of the attempt is that the total estimated price of the project is 0,2% greater than the budgeted price of the project. The deviation of the whole project cost can seem acceptable as the expected deviation is 5%. Nevertheless, looking at the deviation of each cost category, the smallest difference is 11%, which is unacceptable.

The reason for such difference in price between the estimated and actual costs is that these calculations have used different base for pricing each parameter in cost category. The budget has been calculated using historical prices of each parameter whereas the model estimated the price using indexation of each parameter taking into the account the base price in Finland in 2005. Another reason for such deviation is that the relationship of material and labor in each parameter of the actual budget is not identical to the one in the estimation model. Thus the index adjustment may adjust one cost category, but provide an incorrect price level for another category. For example when indexing the price of floor slab which consists of "precast concrete" and "other skilled labor" subcategories, the price of the interior walls indexes as well, because this parameter also contains the same materials assuming that walls consist of precast concrete. This means that if the price database is not adjusted properly, the estimation result may be unreliable. This indicates the importance of quality data mentioned in the beginning of the third chapter of this study.

The result of the price adjustment via indexation provides the possibility to get to the acceptable price level of the whole project, but fails to provide an acceptable price on more detailed level of cost categories. This means that the model cannot be applied in St. Petersburg before the cost estimation nomenclature is adjusted to the market price level. This shows an importance of the historical market data for the cost estimation mentioned earlier in the third chapter of the study. The adjustment can be achieved by manually inputting price levels for categories that cause the biggest price deviation between actual and estimated price.

4.5.4 Advantages, Drawbacks, and Further Usage

Previous section has analyzed cost estimation model scope and price outputs by answering the third research question of the study and concentrating on how accurate are scope and price estimation calculations based on the current estimation methodology. This section will elaborate on current advantages and disadvantages of the model and how can the model be implemented in the residential construction industry of St. Petersburg, Russia. This section will be finalized by addressing the final part of the third research question of the study.

Based on the analysis results, the study can outline the main advantages of using the current cost estimation model for St. Petersburg. First, the model provides a developed framework for accounting technical parameters included in the construction project. It means that each parameter is located under the certain cost category. This allows cost estimation engineers to concentrate more on estimation results rather than nomenclature structure. It also eases the comprehension of estimation output by construction professionals which are not familiar with Talo 80 or typical cost accounting systems in the construction. Thus, it increases the speed of cost estimation, therefore makes the decision making process more efficient for the managers. If without any default framework it takes couple of months to create an estimated project budget, with working cost estimation model it can take up to one or two weeks (Kerkkänen, 2013).

Second, the existing estimation model is flexible and provides reliable base for cost estimation in other markets. Even though the study is limited to residential production, the model is used to estimate project costs of commercial and industrial construction projects.

The cost estimation model implementation has been conducted for example in Denmark and Estonia markets (Kerkkänen, 2013).

Third, the cost estimation model is transparent which makes it easy to identify the source of each calculation. This allows each parameter to be fetched and tested without the need of software coding. The implementation process does not require any major investments and software support as the estimation model is NCC's in-house product based on MS Excel.

After the estimation model testing, the study can outline major model disadvantages. First, the model is based on the case-based reasoning model, which means that the desired preciseness can be achieved mostly through historical data. It means that the model implementation for freshly established business locations can be way to complicated task and may result in estimation model not being valid. For example if NCC would establish construction operations in the market where the company has not performed any projects, it would increase uncertainty during estimation adjustment as there is no exact price and scope calculations to benchmark the output.

Second, the model cannot be used out-of-the-box in location from it does not have pricing data. Even though the model offers a possibility of price adjustment through indexation of cost categories, it is only suitable when the pricing data in the model is from the similar market where the estimation for the construction project is conducted.

Third, the estimation model is not able to predict sudden market price fluctuations. Of course the indexation methodology assumes inflation, but in some extraordinary economic circumstances that might be insufficient.

Fourth, the current estimation model functions as a separate instance and is not integrated into any cost accounting systems. Even though being easy to maintain, it can cause additional complications when integrating estimation results with other financial systems.

Fifth, the model is not used during the design stage of the construction project at the moment. Thus, after the first project cost estimation is made, the result is not benchmarked against the actual budget of the project.

Based on the test results the study can outline the estimation model's potential for further usage. First, it is important to know the approximate project scope and estimated cost for decision makers before the investment decision has been made. Framed scope and preliminary estimations justify the requested investment amount for development projects. Moreover all the respected construction companies in St. Petersburg dedicate sufficient amount of attention towards preliminary construction cost estimation (Boytsov, et al., 2013). Therefore current estimation model in NCC offers efficient solution for construction cost estimation during the initial planning stage of the project by automating tasks that cost estimation engineers would perform manually with each estimation.

From the manager's perspective, the tool gives an outlook of the project's financial potential. For example if NCC decided to acquire certain plot for new residential building construction, with the help of cost estimation model it can estimate the sales price of the construction project to property developer. For example, SATO, Finnish investor into residential housing (Sato Corporation, 2012), is considering to expand their apartment portfolio in St. Petersburg. With the use of estimation model, the NCC can approach

SATO with the calculated project scope before any investments have been made in NCC. As the result, SATO will be able to get the estimated project scope estimated with net leasable area with only 4% deviation. It means that SATO can estimate discounted cash flow model based on the data from NCC. That will give NCC an advantage before other competitors that offer construction services if within a week they will be able to present the possible project scope with all the necessary information for SATO to perform a financial analysis.

From the designer's perspective, the estimation model provides an implementation of design management process used in NCC. In practice it means that it implements the target costing methodology by providing basis for possible project design options. Estimation model gives project scope and limitations for designers in order to achieve the most suitable design option for the underlined project.

5 Summary of the Study and Research Findings

This final chapter of the research will discuss how the study has addressed the research questions of the study and how it was able to provide solution for the research problem. This chapter will also address issues of reliability and validity of the study and will finish with further research and development of the subject.

5.1 Results of the Study

The study has aimed to emphasize the importance of construction cost estimation during the planning phase of the construction project. Also the research elaborated on target costing methodology as a suitable way to steer design in design management process. The study provided an application of target costing through the current estimation model used in NCC. Then the research conducted test estimation based on real construction project and benchmarked against actual calculations. Therefore the objective of the study was to address the issue of premise-based construction cost estimation in St. Petersburg, Russia.

The first research question: "*Why the construction costs estimation is vital for construction project planning? According to the existing studies, what are the main cost estimation methodologies applied by practitioners?*" was addressed in the literature review of the study. The literature review started with defining the cost estimation in the construction industry, then it described the most common approaches towards cost estimation, and finally it defined the term of target costing and its application in cost estimation in the construction industry. The importance of cost estimation in the construction industry was emphasized in third chapter by a real-life example of describing cost estimation model's role and function in the design management process of NCC.

The second research question: "*Using the methodology of cost estimation based on premises' requirements and costs, can the existing in NCC estimation model be implemented in St. Petersburg, Russia?*" was addressed in the second part of the third chapter of the study. The research provided the framework for successful model estimation based on the demands for space and facility cost categories. The research defined and justified the convenience of the default building model usage during the cost estimation process. Third chapter also defined the technical parameters' scope and price estimation technique for the estimation model.

The third research question: "*Is the estimated model reliable for St. Petersburg, Russia?*" is addressed in the fourth chapter of the study by applying estimated model on the case scenario. The estimation has been simulated and benchmarked against the actual budget. The estimation output analysis in the second part of the fourth chapter outlined that the model is not reliable for immediate usage in St. Petersburg, thus requires further development based on the unacceptable price difference of cost categories between estimated and actual results. Nevertheless, the model has to undergo price adjustment of parameters before it can be submitted for company's final usage. The final part of the fourth chapter identifies strengths and weaknesses of the current estimation model and suggests path for further usage for NCC.

For addressing the issue if the structured estimation model in NCC can be applied to another market, the study used real-life case scenario in its research with the actual data. The study has used Finnish construction nomenclature system as the framework for estimated quantity take-off. One of the key findings of the study is that the current cost estimation system can be application for the market in St. Petersburg, Russia. The research has conducted four interviews with industry professionals from NCC in Finland and St. Petersburg office to gather data regarding cost estimation importance and methodology of the current cost estimation model in NCC. The interview identified management's expectations during the testing phase of the first estimation, and the result's analysis has shown that these expectations have been satisfied.

Based on the study results, it can be identified that the current estimation model used in NCC is suitable for implementation and further usage for the market in St. Petersburg, Russia, although it has to undergo thorough price adjustment. The main justification for that claim is that it meets the expectations of the project scope estimation. When the price is adjusted according to the market information, the model should produce reliable results.

5.2 Reliability and Validity

The reliability of the study implies that the measure methodology conducted in the study is consistent. In the case-study of this research it is appropriate to ask a question, whether the reliability and validity were established in the existing model (Creswell, 2003).

The model is considered reliable because it has been developed and used in Finland starting from 1990 and currently it is used as a main instrument to perform construction cost estimations for residential, commercial, and industrial projects (Kerkkänen, 2013). In other words, the methodology of the estimation model is reliable because it has been applied by other estimation engineers with obtaining satisfactory results.

The reliability of the literature review was achieved by using reliable sources which meet the requirements of being a scientific source.

The validity of the study can be analyzed from the perspective of construct validity and external validity. The cost estimation model can be assessed via construct validity by indicating whether it is measures what it claims to measure and whether results are useful (Creswell, 2003). Further usage justified the usefulness of study results. From the perspective of the external validity, the cost estimation methodology can be generalized for other scientific studies. The target costing process is applicable to every production or manufacturing industry. However the result of cost estimation model in NCC can be less generalized for other studies, although it is valid for further research of estimation development, as no estimation is ever 100% correct.

5.3 Recommendations for Further Research and Development

In the literature review part, the study has highlighted the lack of real-life cases in implementation of target costing methodologies in construction cost estimation. Moreover Finland has been one of the success markets in cost estimation methodology implementation and development in the construction area. The reason for mentioning specifically construction industry is this project is conducted for a leading property development company in the Nordic Region and that construction projects require lump sum of upfront investment. Thus the justified to certain degree information at the early stage regarding project scope and estimated cost can be crucial for successful project start-up. It would be useful and interesting to read about how other market players from different markets worldwide resolve the problem of accuracy in estimating project costs at its planning stage.

As the estimation is never 100% correct, so there is always room for development. The first aspect to develop is precision of estimation results, which means that one might research for some external factors influencing the accuracy of construction cost estimation. One way to develop the estimation results' precision is to have the reliable benchmarking system on actual results. Another aspect to develop is the estimation process integration with other systems. Construction companies tend to use many different accounting tools on a corporate level, therefore it may increase estimation process' speed and estimation precision in less if the process would be more integrated with other systems accounting quantity take-off and total project cost calculations. For example in the beginning of the third chapter, the study describes the potential benefit of estimation model integration in the design stage of the construction project for the results' benchmarking.

Regarding the estimation model itself, it is recommended to create the local price database for each market it is used in rather than adjusting the price level only through indexation of cost categories. The estimation result will be more reliable because the model will base the estimation result on the actual figures from the market. The indexation technique used in the estimation model is recommended only for the pricing level adjustment and not formation of the pricing level for the new market.

Table of References

Adeli, H. & Wu, M., 1998. Regularization neural network for construction cost estimation. *Journal Of Construction Engineering & Management,* 124(1), pp. 18-24.

Akintoye, A., 2000. Analysis of factors influencing project cost estimating practice. *Construction Management & Economics,* 18(1), pp. 77-89.

An, S.-H., Kim, G.-H. & Kang, K.-I., 2007. A case-based reasoning cost estimating model using experience by analytic hierarchy process. *Building and Environment,* 42(7), pp. 2573-2579.

Azhar, S., Hein, M. & Sketo, B., 2008. *Building information modeling (BIM): Benefits, risks and challenges..* s.l., s.n.

Ballard, G., 2012. *Should project budgets be based on worth or cost?.* San Diego, s.n., pp. 761-770.

Baloi, D. & Price, A. D., 2003. Modelling global risk factors affecting construction cost performance. *International Journal of Project Management,* May, 21(4), pp. 261-269.

Beck Technology Ltd, 2012. *Features of DProfiler.* [Online]
Available at: http://beck-technology.com/features.html
[Accessed 7 January 2014].

Boytsov, A., Santala, M. & Eskola, P., 2013. *Management Systems in NCC Housing, Russia* [Interview] (25 Novemeber 2013).

Chou, J.-S., 2011. Cost simulation in an item-based project involving construction engineering and management. *International Journal of Project Management,* 29(6), pp. 706-717.

Creswell, J. W., 2003. *Crewell, Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* 2nd ed. Lincoln: SAGE Publications.

DelPico, W. J., 2012. *Estimating Building Costs for the Residential and Light Commercial Construction Professional.* New Jersey: John Wiley & Sons.

Dikmen, I., Birgonul, M. T. & Han, S., 2007. Using fuzzy risk assessment to rate cost overrun risk in international construction projects. *International Journal of Project Management,* 25(5), pp. 494-505.

Doloi, H. K., 2011. Understanding stakeholders' perspective of cost estimation in project management. *International Journal of Project Management,* 29(5), pp. 622-636.

Duverlie, P. & Castelain, J. M., 1999. Cost Estimation During Design Step: Parametric Method versus Case Based Reasoning Method. *The International Journal of Advanced Manufacturing Technology,* 15(12), pp. 895-906.

Edwards, P. J. & Bowen, P. A., 1998. Risk and risk management in construction: a review and future directions for research. *Engineering Construction & Architectural Management,* 5(4), pp. 339-349.

Eskola, P. & Kerkkänen, E., 2013. *Price Adjustment for Cost Estimation in Residential Construction* [Interview] (11 November 2013).

Federal Pricing Center of Russian Federation, 2014. *Federal Registry of Cost Estimation Norms.* [Online]
Available at: http://www.faufccs.ru/federalregister/
[Accessed 5 February 2014].

Feshchenko, A., 2013. *Cost Estimation for Utlilities in Case Study,* St. Petersburg: s.n.

Feshchenko, A., 2014. *Pricing and Indexing of the Construction Projects in Russian Federation,* St. Petersburg: s.n.

Firat, C. E. et al., 2010. *Quantity take-off in model-based systems.* Cairo, s.n.

Gruppa Kompanij Grand, 2014. *Products.* [Online]
Available at: http://www.grandsmeta.ru/products
[Accessed 7 February 2014].

Haahtela, Y. & Kerkkänen, E., 1991. *Tilavaatimukset ja Tilakustannukset.* A1 ed. Helsinki: Rakennuskirja Oy.

Howard, R. & Björk, B.-C., 2008. uilding information modelling–Experts' views on standardisation and industry deployment. *Advanced Engineering Informatics,* 22(2), pp. 271-280.

IBM Corporation, 2013. *SPSS Statistics.* [Online]
Available at: http://www-01.ibm.com/software/analytics/spss/products/statistics/
[Accessed 7 January 2014].

Kerkkänen, E., 2013. *Construction Cost Estimation in NCC* [Interview] (26 August 2013).

Kim, G.-H., An, S.-H. & Kang, K.-I., 2004. Comparison of construction cost estimating models based on regression analysis, neural networks, and case-based reasoning. *Building and Environment,* October, 39(10), pp. 1235 - 1242.

Lee, G., Sacks, R. & Eastman, C. M., 2006. Specifying parametric building object behavior (BOB) for a building information modeling system. *Automation in construction,* 15(6), pp. 758-776.

Mak, S. & Picken, D., 2000. Using risk analysis to determine construction project contingencies. *Journal of Construction Engineering and Management,* 126(2), pp. 130-136.

Pennanen, A., Ballard, G. & Haahtela, Y., 2011. Target costing and designing to targets in construction. *Journal of Financial Management of Property and Construction,* 16(1), pp. 52-63.

Pennanen, A., Haahtela, Y. & Väänänen, H., 2005. *Workplace planning and target costing techniques in project and facility management.* Helsinki, s.n., pp. 1-12.

Petrov, K. & Soloshenko, J., 2013. *Technical Parameters for Case Study Project* [Interview] (23 October 2013).

Saari, A., 2008. Computational design concept analysis: a Nordic comparison of four apartment buildings. *Structural Survey,* 26(1), pp. 29-37.

Sato Corporation, 2012. *Annual Report 2012,* Helsinki: s.n.

The Chartered Institute of Building, 1997. *Code of Estimating Practice.* 6 ed. Chichester(West Sussex): Blackwell Publishing.

Touran, A., 1993. Probabilistic Cost Estimating with Subjective Correlations. *Journal of Construction Engineering and Management,* 119(1), pp. 58-71.

Ward Systems Group, Inc., 2013. *NeuroShell Predictor and Classifier.* [Online]
Available at: http://www.wardsystems.com/engine.asp
[Accessed 7 October 2013].

Wizardsoft Corporation, 2013. *Products.* [Online]
Available at: http://wizardsoft.ru/product/smetawizard
[Accessed 7 February 2014].

Zimina, D., Ballard, G. & Pasquire, C., 2012. Target value design: using collaboration and a lean approach to reduce construction cost. *Construction Management and Economics,* 30 April, 30(5), pp. 383-389.

Data

- NCC Construction, Finland
- NCC Housing, Russia

Interviewees

- Pekka Eskola, NCC Housing, Russia, Head of Technical Department
- Esko Kerkkänen, NCC Construction, Finland, Head of Estimation Department
- Aleksander Boytsov, NCC Housing, Russia, Head of Design Group
- Marko Santala, NCC Housing, Russia, Project Manager

Appendix

Interview with NCC Housing, St. Petersburg, Russia

The answers and comments provided by the interviewees are subjected to their own opinion and based on the information used in NCC Group. The opinions do not claim the absolute way of conducting certain procedures but are only persons' recommendations and views.

The structure of the interview is provided below.

1) **What is the role of the construction cost estimation procedure during the early planning stage of the construction project?**
   a) What methods construction industry professionals currently use for cost estimation?
   b) How thorough those professionals are during the cost estimation process?
2) **Current method of cost estimation procedure in NCC Housing in Russia**
   a) What is the suggested path for the cost estimation methodology development? More quality or speed oriented?
3) **Design management process in NCC Housing, Russia.**
   a) During which phase estimation model would bring the most added value to the whole design process?
   b) Is the a need for estimation model package integration into other operations during the design management process? Which ones? Why?
4) **Other comments towards cost estimation and estimation model implementation**

Interview with NCC Construction, Finland

1) **The role of the estimation model in NCC Construction Finland**
   a) Who uses the model?
   b) What is the purpose of it?
   c) What are the main advantages and weaknesses of the model?
2) **Other contributors to cost estimation methodology in Finland and worldwide**
   a) Who are the major market players in implementation of the cost estimation methodology?
   b) What is the difference between NCC in-house model and other alternatives on the market?
3) **Price adjustment in estimation model**
   a) What is the method of price adjustment and maintenance implemented in the model?
   b) Is the method reliable?